KEITHLEY

Model 199 System DMM Scanner Instruction Manual

Contains Operating and Servicing Information

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WARRANTY

Keithley Instruments, Inc. warrants this product to be free from defects in material and workmanship for a period of 1 year from date of shipment. During the warranty period, we will, at our option, either repair or replace any product that proves to be defective.

To exercise this warranty, write or call your local Keithley representative, or contact Keithley headquarters in Cleveland, Ohio. You will be given prompt assistance and return instructions. Send the instrument, transportation prepaid, to the indicated service facility. Repairs will be made and the instrument returned, transportation prepaid. Repaired products are warranted for the balance of the original warranty period, or at least 90 days.

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This warranty is in lieu of all other warranties, expressed or implied, including any implied warranty of merchantability or fitness for a particular use. Keithley Instruments, Inc. shall not be liable for any indirect, special or consequential damages.

STATEMENT OF CALIBRATION

This instrument has been inspected and tested in accordance with specifications published by Keithley Instruments, Inc.

The accuracy and calibration of this instrument are traceable to the National Bureau of Standards through equipment which is calibrated at planned intervals by comparison to certified standards maintained in the Laboratories of Keithley Instruments, Inc.

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Instruction Manual
Model 199
System DMM Scanner

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SAFETY PRECAUTIONS

The following safety precautions should be observed before operating the Model 199.

This instrument is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read over the manual carefully before operating this instrument.

Exercise extreme caution when a shock hazard is present at the instrument's input. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V rms or 42.4V peak are present. **A good safety practice is to expect that a hazardous voltage is present in any unknown circuit before measuring.**

Inspect the test leads for possible wear, cracks or breaks before each use. If any defects are found, replace the test leads.

For optimum safety do not touch the test leads or the instrument while power is applied to the circuit under test. Turn the power off and discharge all capacitors, before connecting or disconnecting the instrument. Always disconnect all unused test leads from the instrument.

Do not touch any object which could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface, capable of withstanding the voltage being measured.

Exercise extreme safety when testing high energy power circuits (AC line or mains, etc). Refer to the High Energy Circuit Safety Precautions found in paragraph 2.6 (Basic Measurements).

Do not exceed the instrument's maximum allowable input as defined in the specifications and operation section.

SPECIFICATIONS

DC VOLTS (5½ Digits)

RANGE	RESOLUTION	INPUT RESISTANCE	ACCURACY[1] ±(%rdg + counts) 24 Hours[2] 23°±1°C	90 Days 18°-28°C	1 Year 18°-28°C
300 mV	1 μV	>1 GΩ	0.004 + 3[3]	0.009 + 3[3]	0.012 + 3[3]
3 V	10 μV	>1 GΩ	0.003 + 2	0.006 + 2	0.007 + 2
30 V	100 μV	11 MΩ	0.004 + 2	0.008 + 2	0.009 + 2
300 V	1 mV	10 MΩ	0.004 + 2	0.008 + 2	0.009 + 2

[1]For 4½-digit accuracy, count error is 5 (except 15 on 300mV range).
[2]Relative to calibration standards.
[3]When properly zeroed.

CMRR: >120dB at dc, 50Hz or 60Hz (±0.05%) with 1kΩ in either lead.

NMRR: >60dB at 50Hz or 60Hz (±0.05%).

MAXIMUM ALLOWABLE INPUT: 300V rms or 425V peak, whichever is less.

TRMS AC VOLTS (5½ Digits)

RANGE	RESOLUTION	ACCURACY[1] ±(%rdg + counts) 1 Year, 18°-28°C 20 Hz - 50 Hz[2]	50 Hz - 200 Hz[2]	200 Hz - 20 kHz[2]	20 kHz - 100 kHz[3]
300 mV	1 μV	2 + 100	0.35 + 100	0.15 + 200	2.0 + 300
3 V	10 μV	2 + 100	0.35 + 100	0.15 + 200	1.5 + 300
30 V	100 μV	2 + 100	0.35 + 100	0.15 + 200	1.5 + 300
300 V	1 mV	2 + 100	0.35 + 100	0.15 + 200	1.5 + 300

[1]For 4½-digit accuracy, divide count error by 10; 4½-digit specifications apply for inputs >200Hz.
[2]Sinewave inputs >2000 counts.
[3]Sinewave inputs >20,000 counts.

RESPONSE: True root mean square, ac coupled.

CREST FACTOR (ratio of peak to rms): Up to 3:1 allowable.

NON-SINUSOIDAL INPUTS (>20,000 counts):
For rectified sine wave, add 0.3% of reading to above specifications for fundamental frequencies <20kHz.
For pulse waveforms, add 0.3% of reading for fundamental frequencies <1kHz, or 3.5% for frequencies <10kHz.

INPUT IMPEDANCE: 1MΩ shunted by <100pF.

MAXIMUM ALLOWABLE INPUT: 300V rms or 425V peak, 10^7V•Hz, whichever is less.

CMRR: >60dB at 50Hz or 60Hz (±0.05%) with 1kΩ in either lead.

SETTLING TIME: 1 second to within 0.1% of change in reading.

dB (ref = 1V):

INPUT	RESOLUTION	ACCURACY ±dB 1 Year, 18°-28°C 20 Hz-20 kHz	20 kHz-100 kHz
−34 to +49 dB (20 mV to 300 V)	0.01 dB	0.2	0.4
−54 to −34 dB (2 mV to 20 mV)	0.01 dB	1.1	—

OHMS (5½ Digits)

RANGE	RESOLUTION	NOMINAL I-SHORT	ACCURACY[1] ±(%rdg + counts) 24 Hours[4] 23° ±1°C	90 Days 18°-28°C	1 Year 18°-28°C
300 Ω[2]	1 mΩ	1.7 mA	0.005 + 4[3]	0.009 + 4[3]	0.012 + 4[3]
3 kΩ[2]	10 mΩ	1.7 mA	0.004 + 2	0.008 + 3	0.009 + 3
30 kΩ[2]	100 mΩ	160 μA	0.004 + 2	0.008 + 3	0.009 + 3
300 kΩ	1 Ω	50 μA	0.014 + 2	0.024 + 3	0.026 + 3
3 MΩ	10 Ω	5 μA	0.02 + 2	0.03 + 3	0.03 + 3
30 MΩ	100 Ω	0.5 μA	0.1 + 5	0.12 + 5	0.12 + 5
300 MΩ	1 kΩ	0.5 μA	2.0 + 5	2.0 + 5	2.0 + 5

[1]For 4½-digit accuracy, count error is 5 (except 15 on 300Ω range).
[2]4-wire accuracy, 300Ω-30kΩ ranges.
[3]When properly zeroed.
[4]Relative to calibration standards.

CONFIGURATION: Automatic 2- or 4-wire.

MAXIMUM ALLOWABLE INPUT: 300V rms or 425V peak, whichever is less.

OPEN CIRCUIT VOLTAGE: <5.5V.

DC AMPS (5½ Digits)

RANGE	RESOLUTION	ACCURACY[1] ±(%rdg + counts) 1 Year, 18°-28°C	MAXIMUM VOLTAGE BURDEN
30 mA	100 nA	0.05 + 15	0.4 V
3 A	10 μA	0.1 + 15	2 V

[1]For 4½-digit accuracy, count error is 20.

MAXIMUM ALLOWABLE INPUT: 3A. Protected with 3A, 250V fuse accessible from front panel.

TRMS AC AMPS (5½ Digits)

RANGE	RESOLUTION	ACCURACY[1] ±(%rdg + counts) 1 Year, 18°-28°C 20 Hz-45 Hz	45 Hz-10 kHz	MAXIMUM VOLTAGE BURDEN
30 mA	100 nA	2 + 100	0.6 + 100	0.4 V
3 A	10 μA	2 + 100	0.6 + 100	2 V

[1]Inputs >2000 counts. For 4½-digit accuracy, divide count error by 10; 4½-digit specifications apply for inputs >200Hz.

RESPONSE: True root mean square, ac coupled.

CREST FACTOR (ratio of peak to rms): Up to 3:1 allowable at ⅔ full range.

NON-SINUSOIDAL INPUTS: Specified accuracy for fundamental frequencies <1kHz.

MAXIMUM ALLOWABLE INPUT: 3A. Protected with 3A, 250V fuse accessible from front panel.

SETTLING TIME: 1 second to within 0.1% of final reading.

dB (ref = 1mA):

INPUT	RESOLUTION	ACCURACY ±dB 1 Year, 18°-28°C 20 Hz-10 kHz
−14 to +69 dB (200 μA to 3 A)	0.01 dB	0.6

MAXIMUM READING RATES (Readings/Second)[1]

DCV, DCA, ACV, ACA

RESOLUTION	Continuous Into Memory MUX: OFF	Continuous Into Memory MUX: ON	External Trigger Into Memory MUX: OFF	External Trigger Into Memory MUX: ON	Triggered Via IEEE-488 Bus[2] MUX: OFF	Triggered Via IEEE-488 Bus[2] MUX: ON
4½-Digit	65	65	150	62	80	49
5½-Digit	35 (29)	9 (7.5)	40 (33)	9 (7.5)	34 (29)	9 (7.5)

OHMS

RESOLUTION	Continuous Into Memory MUX: OFF	Continuous Into Memory MUX: ON	External Trigger Into Memory MUX: OFF	External Trigger Into Memory MUX: ON	Triggered Via IEEE-488 Bus[2] MUX: OFF	Triggered Via IEEE-488 Bus[2] MUX: ON
4½-Digit	43	20	47	20	30	18
5½-Digit	16 (13)	9 (7.5)	16 (13)	9 (7.5)	15 (12.5)	9 (7.5)

[1]Reading rates are for fixed range readings with filters off, for 3V, 3kΩ, and 30mA ranges. 5½-digit rate is for 60Hz operation. Values in parentheses are for 50Hz operation.
[2]One shot on TALK.

STORAGE & SCANNING CAPABILITIES

500-Reading Memory: Stores reading, range, and scanner channel.

Trigger: One shot or continuous from front panel, IEEE-488 bus, and rear panel BNC.

Programmable Reading Interval: 15ms to 999.999s.

Programmable Trigger Delay: 1ms to 999.999s.

WITH MODEL 1992 8-CHANNEL SCANNER

Programmable Configuration: 2- or 4-pole.

Programmable Channel Limit: 1 to 8.

Programmable Scanning Modes: Manual, step, and scan.

Ratio: Channels 2 through 8 referenced to Channel 1.

IEEE-488 BUS IMPLEMENTATION

MULTILINE COMMANDS: DCL, LLO, SDC, GET, GTL, UNT, UNL, SPE, SPD.

UNILINE COMMANDS: IFC, REN, EOI, SRQ, ATN.

INTERFACE FUNCTIONS: SH1, AH1, T6, TE0, L4, LE0, SR1, RL1, PP0, DC1, DT1, C0, E1.

All front panel functions and programs are available over the IEEE-488 bus, in addition to Status, Service Request, Output Format, EOI, Trigger, Terminator, Display Message, and Non-Volatile TRANSLATOR.

IEEE-488 address is programmable from the front panel.

MODEL 1992 SCANNER OPTION

CONTACT CONFIGURATION: 8-channel 2-pole, or 4-channel 4-pole.

CONTACT POTENTIAL: $<1\mu V$ per contact pair.

MAXIMUM SWITCHING RATE: 40 channels/second, including Model 199 4½-digit DCV reading time.

CONNECTOR TYPE: Quick disconnect screw terminals, #14 AWG maximum wire size.

MAXIMUM SIGNAL LEVEL: 200V peak, 100mA, resistive load.

CONTACT LIFE: $>10^6$ operations (at maximum signal level); $>10^8$ operations (cold switching).

CONTACT RESISTANCE: $<1\Omega$.

ISOLATION BETWEEN ANY TWO TERMINALS: $>10^9\Omega$, <75pF.

ISOLATION BETWEEN ANY TERMINAL AND EARTH: $>10^9\Omega$, <150pF.

COMMON MODE VOLTAGE: 350V peak between any terminal and earth.

MAXIMUM VOLTAGE BETWEEN ANY TWO TERMINALS: 200V peak.

MAXIMUM VOLTAGE BETWEEN ANY TERMINAL AND MODEL 199 INPUT LO: 200V peak.

DIMENSIONS, WEIGHT: 25mm high × 130mm wide × 170mm deep (⅞ in. × 5 in. × 6½ in.). Adds 0.3kg (8 oz.) to Model 199.

GENERAL

MAXIMUM READING: 302,999 counts in 5½-digit mode.

CONNECTORS: Measurement: Switch selectable front or rear, safety jacks. **Digital:** TRIGGER input and METER COMPLETE output on rear panel, BNCs.

WARMUP: 2 hours to rated accuracy.

TEMPERATURE COEFFICIENT (0°-18°C & 28°-50°C): $<\pm(0.1 \times$ applicable accuracy specification$)/°C$.

ISOLATION: Input LO to IEEE LO or power line ground: 500V peak. 5×10^5 V•Hz maximum. $>10^9\Omega$ paralleled by 400pF.

OPERATING ENVIRONMENT: 0°-50°C, 80% relative humidity up to 35°C; linearly derate 3% RH/°C, 35°-50°C (0%-60% RH up to 28°C on 300MΩ range).

STORAGE ENVIRONMENT: −25° to +65°C.

POWER: 105-125V or 210-250V, rear panel switch selected, 50Hz or 60Hz, 20VA maximum. 90-110V and 180-220V versions available upon request.

DIMENSIONS, WEIGHT: 90mm high × 220mm wide × 330mm deep (3½ in. × 8⅝ in. × 12⅞ in.). Net weight 3kg (6 lbs., 8 oz.).

ACCESSORIES SUPPLIED: Model 1751 Safety Test Leads, Instruction Manual.

ACCESSORIES AVAILABLE:

Model 1992: 8-Channel Scanner
Model 1993: Quick Disconnect Scanner Connector Kit
Model 1998-1: Single Fixed Rack Mounting Kit
Model 1998-2: Dual Fixed Rack Mounting Kit
Model 1651: 50-Ampere Shunt
Model 1681: Clip-On Test Lead Set
Model 1682A: RF Probe
Model 1685: Clamp-On Current Probe
Model 1751: General Purpose Test Leads
Model 1754: Universal Test Lead Kit
Model 5806: Kelvin Clip Leads
Model 7007-1: Shielded IEEE-488 Cable, 1m
Model 7007-2: Shielded IEEE-488 Cable, 2m
Model 7008-3: IEEE-488 Cable, 0.9m (3 ft.)
Model 7008-6: IEEE-488 Cable, 1.8m (6 ft.)

199 Front Panel Operation

TRIG SETUP

SHIFT/TRIG SETUP to enter menu.

NEXT to scroll to next menu option.

Trigger ▲/▼
- CONTINUOUS: Reading, scanning, and storing rates controlled by INTERVAL.
- ONE SHOT.

DELAY — 0sec to 999.999sec

INTERVAL ▲/▼
- SELECT OFF: Interval ≥175msec, depending on other programmed parameters.
- SELECT ON: User-programmed interval (15msec to 999.999sec).

DMM SETUP

SHIFT/DMM SETUP to enter menu.

NEXT to scroll to next menu option.

REV — Displays current software revision level.

MUX ▲/▼
- MUX OFF: Turns off autocal routines for faster reading rates.
- MUX ON: Recommended for best accuracy.

IEEE — Use numeric keys to program IEEE-488 primary address (0-30).

FREQ ▲/▼
- FREQ=50HZ. Line frequency.
- FREQ=60HZ. Line frequency.

SAVE ▲/▼
- SAVE YES: Saves present configuration.
- SAVE NO

LEDS ▲/▼
- LEDS ON: Test front panel LEDs and annunciators.
- LEDS OFF

DEBUG ▲/▼
- DEBUG YES: Enter troubleshooting mode.
- DEBUG NO

RESET ▲/▼
- RESET YES: Returns unit to factory default configuration.
- RESET NO

ONE-SHOT OPERATION

In the one-shot trigger mode, each reading consists of multiple conversions to fill the Running Average User Filter (30 conversions), or the Running Average Internal Filter (5½d only, varies by ranges and function--see manual). For this reason, trigger-to-reading time could be several seconds, depending on filtering. When filters are off ("P0" command over the bus can be SAVEd), readings are made up of only one conversion.

STORE

- SHIFT/STORE to enter data store.
- SIZE = 1 to 500, or SIZE = 000 for wrap around.
- NEXT to exit size select.
- TRIGGER to initiate storage.
- Any function key to cancel storage.
- RCL flashes when data store is full.

RECALL

- SHIFT/RECALL to enter recall.
- NEXT to view data at displayed location.
- ▲ or ▼ to scroll through locations.
- RECALL again to select desired location.
- NEXT to display data.
- NEXT to exit recall mode.

ERROR MESSAGES

UNCAL	EEPROM failure on power up
OVERFL	Overrange
TRIGGER OVERRUN	Unit triggered while processing reading.
INTERVAL OVERRUN	Interval too short for selected configuration.
AC ONLY	dB selected with unit not in ACV or ACA.
NO RANGE	Pressing range button in dB.
CAL LOCKED	Calibration locked out when calibrating.
CONFLICT	Unit in invalid state when calibrating (i.e., autorange).
NO DATA	Entering recall with no data stored.
NO SCANNER	Scanner not installed.

TYPICAL 5½ DIGIT CONVERSION TIMES

MUX ON, DCV, ACV, ACA: 110msec (133msec)
MUX OFF: 28msec (33msec)

MUX ON, OHMS, 300kΩ range and lower: 110msec (133msec)
MUX OFF: 63msec (78msec)

(Times in parenthesis are for 50Hz operation)

TYPICAL AUTORANGING TIMES

DCV, DCA	350msec
ACV, ACA	1.4sec
OHMS (300kΩ range and lower)	500msec

(Times shown are to correct range and do not include conversion times for final reading.)

Scanner Operation

SCAN SETUP

SHIFT/SCAN SETUP to enter menu.

NEXT to scroll to next menu option.

POLE ▲/▼
- 2 POLE
- 4 POLE

Mode ▲/▼
- MANUAL: Allows channel to be manually closed with SCANNER key.
- STEP: Increments one channel per interval or trigger.
- SCAN: Scans one set of channels per interval or trigger (minimum time between channels).

RATIO ▲/▼
- ON: Channels 2 through 8 referenced to channel 1.
- OFF

- Ratio operates only on a fixed range.
- Range changes will restart at channel 1.
- In MANUAL, at least one reading must be taken on channel 1 before attempting to display ratio on channels 2-8.

ACTIVATING THE SCANNER

SCANNER followed by number (1-8) activates the scanner.
- In MANUAL, channel number selects channel to be closed.
- In STEP or SCAN, number selects channel limits and starts scanning process.

STOPPING THE SCANNER (Opening all Channels)

SCANNER followed by "0".

DETERMINING SCANNING INTERVAL

- Scanning without selecting interval
  - —Program INTERVAL SELECT to OFF.
  - —Interval is ≥175msec, depending on other selected parameters.
  - —INTERVAL OVERRUN message will not be displayed.
- Minimum Interval Time Calculation
  - —Interval time is the sum of:
    1. (conversions per channel) × (conversion time)
    2. Programmed DELAY time per channel
    3. Break-before-make time (17msec)
    4. Auto range time (if used)
  - —In STEP mode, calculated time above is the INTERVAL setting.
  - —In SCAN mode, (sum of 1-4) × (number channels scanned) is the minimum interval setting.

SCANNER OPERATION NOTES

- When using the scanner with STEP or SCAN switching, the DMM will take readings on each channel as if it were in the one-shot mode whether programmed to CONTINUOUS or ONE SHOT:
  - —Conversions are automatically synchronized to channel closures. Channels will not close in the middle of conversions.
  - —Any programmed DELAY is inserted between channel closure and start of conversion (with scanner disabled, DELAY is inserted between trigger and start of conversion).
  - —Readings on each channel consist of multiple conversions to fill the Running Average User Filter (30 conversions), or Running Average Internal Filter when active (5½d only, varies by range and function; see manual).
- Scanner switching is break-before-make. The time required to change channels is approximately 17msec, which includes break-before-make relay time settling time.
- When using the scanner with ACV or ACA, a DELAY time must be programmed to accomodate AC converter settling time (typically >1sec). See Model 199 specifications.
- The scanner operates with the set of instrument parameters programmed prior to start of scanning. Changing any of these parameters, range function, filter, etc., during scanning will restart the scanner at channel 1. Use autorange if range changes are required while scanning.

USING SCANNER WITH DATA STORE

- Select desired scanner parameters and interval.
- Activate scanning (SCANNER, channel limit).
- Program data store size.
- TRIGGER will start data store and automatically restart scanning at channel 1 synchronized with data store location 1.

EXAMPLE OF FAST SCANNING

1. Select 3V DC range and function, 4½-digit resolution, FLTR off.
2. Program ONE SHOT trigger.
3. Select SCAN mode.
4. Select SCANNER "8" to set limit to 8.
5. Use TRIGGER to initiate a scan of the set of eight channels.

199 IEEE-488 Programming

DEVICE-DEPENDENT COMMANDS

EXECUTE

X	Execute other device-dependent commands.

FUNCTION

F0	DC volts
F1	AC volts
F2	Ohms
F3	DC current
F4	AC current
F5	ACV dB
F6	ACA dB

RANGE

	DCV	ACV	DCA	ACA	Ohms	ACV dB	ACA dB
R0	Auto	Auto	Auto	Auto	Auto	Auto	Auto
R1	300mV	300mV	30mA	30mA	300 Ω	Auto	Auto
R2	3V	3V	3A	3A	3kΩ	Auto	Auto
R3	30V	30V	3A	3A	30kΩ	Auto	Auto
R4	300V	300V	3A	3A	300kΩ	Auto	Auto
R5	300V	300V	3A	3A	3MΩ	Auto	Auto
R6	300V	300V	3A	3A	30MΩ	Auto	Auto
R7	300V	300V	3A	3A	300MΩ	Auto	Auto

ZERO

Z0	Zero disabled
Z1	Zero enabled
Z2	Zero enabled using a zero value (V)

FILTER

P0	Internal and front panel filter disabled
P1	Internal filter enabled
P2	Front panel filter enabled

RATE

S0	4½-digit resolution, 2.59msec integration period
S1	5½-digit resolution, line cycle integration (16.67msec, 60Hz; 20msec, 50Hz)

TRIGGER MODE

T0	Continuous on Talk
T1	One-shot on Talk
T2	Continuous on GET
T3	One-shot on GET
T4	Continuous on X
T5	One-shot on X
T6	Continuous on External Trigger
T7	One-shot on External Trigger

READING MODE

B0	Readings from A/D converter
B1	Individual readings from data store
B2	All readings from data store (buffer dump)

DATA STORE SIZE

I0	Wrap around data store mode
In	Data store of n (n=1 to 500)

INTERVAL

Q0	Default interval, 175msec (SELECT OFF)
Qn	n=interval in milliseconds (15msec to 999999msec)

VALUE

V±nn.nnnn or V±n.nnnnnnE+n	Calibration value, zero value

CALIBRATION

C0	Calibrate first point using value (V)
C1	Calibrate second point using value (V)
C2	Calibrate third point using value (V)

DEFAULT CONDITIONS

L0	Restore factory default conditions and save (L1)
L1	Save present machine states as default conditions

DATA FORMAT

G0	Reading with prefix.
G1	Reading without prefix.
G2	Reading and buffer location with prefix.
G3	Reading and buffer location without prefix.
G4	Reading and channel with prefix.
G5	Reading and channel without prefix.
G6	Reading, buffer location, and channel with prefix
G7	Reading, buffer location, and channel without prefix

SRQ

M0	Disable
M1	Reading overflow
M2	Data store full
M4	Data store half full
M8	Reading done
M16	Ready
M32	Error

EOI AND BUS HOLD-OFF

K0	Enable EOI and bus hold-off on X default
K1	Disable EOI, enable bus hold-off on X
K2	Enable EOI, disable bus hold-off on X
K3	Disable both EOI and bus hold-off on X

TERMINATOR

Y0	CR LF
Y1	LF CR
Y2	CR
Y3	LF

STATUS

U0	Send machine status word
U1	Send error conditions
U2	Send Translator word list
U3	Send buffer size
U4	Send current value of "V"
U5	Send input switch status (front/rear)

MULTIPLEX

A0	Auto/Cal multiplex disabled
A1	Auto/Cal multiplex enabled

DELAY

Wn	n=delay period in milliseconds, (0msec to 999999msec)

SELF-TEST

J0	Test, ROM, RAM, E²PROM

HIT BUTTON

Hn	Hit front panel button number n

DISPLAY

Da	Display up to 10 character message. a=character
D	Cancel display mode

SCANNER PROGRAMMING COMMANDS

SCANNER SETUP

MANUAL

	2-pole	4-pole
N0	All channels open	
N1	1	1
N2	2	2
N3	3	3
N4	4	4
N5	5	CHAN 4 MAX ERROR
N6	6	CHAN 4 MAX ERROR
N7	7	CHAN 4 MAX ERROR
N8	8	CHAN 4 MAX ERROR
N9	CHAN 8 MAX ERROR	CHAN 4 MAX ERROR

STEP

	2-Pole Limit	4-Pole Limit
N10	Stop scan, all channels open	
N11	1	1
N12	2	2
N13	3	3
N14	4	4
N15	5	CHAN 4 MAX ERROR
N16	6	CHAN 4 MAX ERROR
N17	7	CHAN 4 MAX ERROR
N18	8	CHAN 4 MAX ERROR
N19	CHAN 8 MAX ERROR	CHAN 4 MAX ERROR

SCAN

	2-Pole Limit	4-Pole Limit
N20	Stop scan, all channels open	
N21	1	1
N22	2	2
N23	3	3
N24	4	4
N25	5	CHAN 4 MAX ERROR
N26	6	CHAN 4 MAX ERROR
N27	7	CHAN 4 MAX ERROR
N28	8	CHAN 4 MAX ERROR

POLE/RATIO

O0	2-pole
O1	4-pole
O2	2-pole ratio
O3	4-pole ratio

SCAN INTERVAL

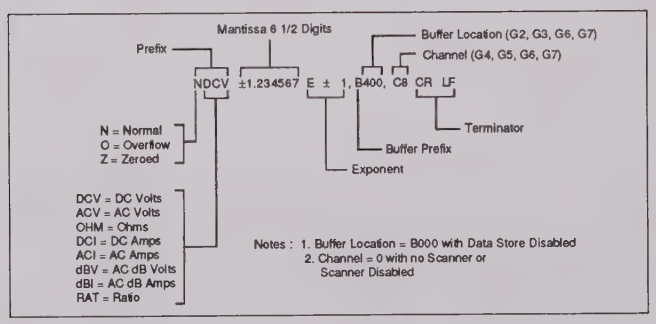
Q0	Default 175msec interval (SELECT OFF)
Qn	n=interval in msec (15-999999msec)

TRIGGER DELAY*

Wn	n=delay in msec (0-999999msec)

*Delay to be used as channel settling time.

DATA FORMAT

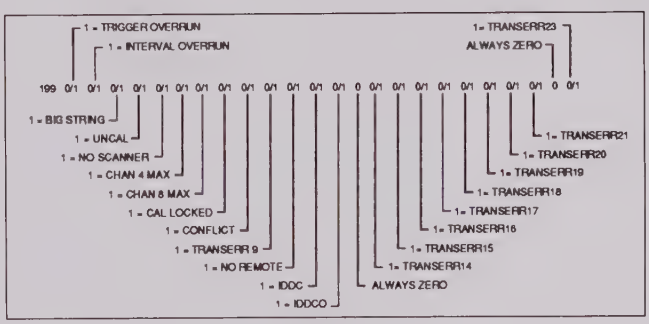

Mantissa 6 1/2 Digits
Prefix
Buffer Location (G2, G3, G6, G7)
Channel (G4, G5, G6, G7)
NDCV ±1.234567 E ± 1, B400, C8 CR LF
Terminator
Buffer Prefix
Exponent
N = Normal
O = Overflow
Z = Zeroed
DCV = DC Volts
ACV = AC Volts
OHM = Ohms
DCI = DC Amps
ACI = AC Amps
dBV = AC dB Volts
dBI = AC dB Amps
RAT = Ratio
Notes : 1. Buffer Location = B000 with Data Store Disabled
2. Channel = 0 with no Scanner or Scanner Disabled

STATUS WORD FORMATS

U0 Status Word Format

```
FACTORY DEFAULT
199 1 0 0 0 0 0 00 0 0   000000   4 1 6   000000   0 0 0 0    0/1
                                                        CAL
199 A B F G J K NN 0 P QQQQQQ R S T WWWWWW Y Z SW SCANNER
```

U1 Status Word Format


1 = TRIGGER OVERRUN
1 = INTERVAL OVERRUN
1= TRANSERR23
ALWAYS ZERO
199 0/1 0/1 0/1 0/1 0/1 0/1 0/1 0/1 0/1 0/1 0/1 0/1 0/1 0 0/1 0/1 0/1 0/1 0/1 0/1 0/1 0 0/1
1 = BIG STRING
1 = UNCAL
1 = NO SCANNER
1 = CHAN 4 MAX
1 = CHAN 8 MAX
1 = CAL LOCKED
1 = CONFLICT
1 = TRANSERR 9
1 = NO REMOTE
1 = IDDC
1 = IDDCO
ALWAYS ZERO
1 = TRANSERR14
1 = TRANSERR15
1 = TRANSERR16
1 = TRANSERR17
1 = TRANSERR18
1 = TRANSERR19
1 = TRANSERR20
1 = TRANSERR21

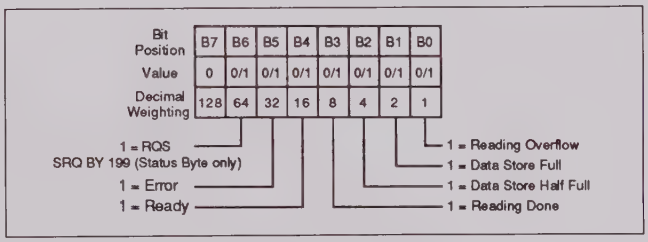
U2: Returns Translator word list.

U3: Returns data store size (SZE = 000).

U4: Returns present value programmed with V command in floating point.

U5: Returns INPUT switch status (0=front, 1=rear).

SRQ MASK AND STATUS BYTE FORMAT


Bit Position B7 B6 B5 B4 B3 B2 B1 B0
Value 0 0/1 0/1 0/1 0/1 0/1 0/1 0/1
Decimal Weighting 128 64 32 16 8 4 2 1
1 = RQS
SRQ BY 199 (Status Byte only)
1 = Error
1 = Ready
1 = Reading Overflow
1 = Data Store Full
1 = Data Store Half Full
1 = Reading Done

TRANSLATOR

Translator Words and Characters

Translator Word or Character	Description
ALIAS	Defines Translator words.
;	Terminates definition string.
$	Wildcard definition character.
NEW	Enabled Translator.
OLD	Disables Translator.
SAVE	Saves Translator words as power-up default.
LIST	Returns list of Translator words.
FORGET	Purges Translator words from memory.

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SECTION 1
General Information

1.1 INTRODUCTION

The Keithley Model 199 System DMM Scanner is a five function autoranging digital multimeter. At 5½ digit resolution, the LED display can display ±302,999 counts. The range of this analog-to-digital (A/D) converter is greater than the normal ±199,999-count A/D converter used in many 5½ digit DMMs. The built-in IEEE-488 interface makes the instrument fully programmable over the IEEE-488 bus. The Model 199 can make the following basic measurements:

1. DC voltage measurements from 1μV to 300V.
2. Resistance measurements from 1mΩ to 300MΩ.
3. TRMS AC voltage measurements from 1μV to 300V.
4. DC current measurements from 100nA to 3A.
5. TRMS AC current measurements from 100nA to 3A.

In addition to the above mentioned measurement capabilities, the Model 199 can make AC dB voltage and current measurements.

1.2 FEATURES

Some important Model 199 features include:

- 10 Character Alphanumeric Display—Easy to read 14-segment LEDs used for readings and front panel messages.
- Zero—Used to cancel offsets or establish baselines.
- Data Store—Can store up to 500 readings and is accessible over the bus or from the front panel.
- Digital Calibration—The instrument may be digitally calibrated from either the front panel or over the bus.
- User Programmable Default Conditions—Any instrument measurement configuration can be established as the power-up default conditions.
- Translator Software—User defined words (stored in non-volatile memory) can be used to replace standard command strings over the IEEE-488 bus.
- Optional Field-Installable Internal Scanner—Allows the unit to switch up to 8, 2-pole channels, or 4, 4-pole channels.

1.3 WARRANTY INFORMATION

Warranty information may be found on the inside front cover of this manual. Should it become necessary to exercise the warranty, contact your Keithley representative or the factory to determine the proper course of action. Keithley Instruments maintains service facilities in the United States, United Kingdom and throughout Europe. Information concerning the application, operation or service of your instrument may be directed to the applications engineer at any of these locations. Check the inside front cover for addresses.

1.4 MANUAL ADDENDA

Information concerning improvements or changes to the instrument which occur after the printing of this manual will be found on an addendum sheet included with the manual. Be sure to review these changes before attempting to operate or service the instrument.

1.5 SAFETY SYMBOLS AND TERMS

The following safety symbols and terms are used in this manual or found on the Model 199.

The symbol on the instrument denotes that the user should refer to the operating instructions in this manual.

The on the instrument denotes that a hazardous potential may be present on the terminal(s). Standard safety practices should be observed when such dangerous levels are encountered.

The **WARNING** used in this manual explains dangers that could result in personal injury or death.

The **CAUTION** used in this manual explains hazards that could damage the instrument.

1.6 SPECIFICATIONS

Detailed Model 199 specifications may be found preceding the Table of Contents of this manual.

1.7 INSPECTION

The Model 199 System DMM was carefully inspected, both electrically and mechanically before shipment. After unpacking all items from the shipping carton, check for any obvious signs of physical damage that may have occurred during transit. Report any damage to the shipping agent. Retain and use the original packing materials in case reshipment is necessary. The following items are shipped with every Model 199 order:

Model 199 System DMM
Model 199 Instruction Manual
Safety shrouded test leads (Model 1751).
Additional accessories as ordered.

If an additional instruction manual is required, order the manual package (Keithley Part Number 199-901-00). The manual package includes an instruction manual and any applicable addenda.

1.8 USING THE MODEL 199 MANUAL

This manual contains information necessary for operating and servicing the Model 199 System DMM. The information is divided into the following sections:

- Section 1 contains general information about the Model 199 including that necessary to inspect the instrument and get it operating as quickly as possible.
- Section 2 contains detailed operating information on using the front panel controls and programs, making connections, and basic measuring techniques for each of the available measuring functions.
- Section 3 contains the information necessary to connect the Model 199 to the IEEE-488 bus and program operating modes and functions from a controller.
- Section 4 contains performance verification procedures for the instrument. This information will be helpful if you wish to verify that the instrument is operating in compliance with its stated specifications.
- Section 5 contains a description of operating theory. Analog, digital, power supply, and IEEE-488 interface operation is included.
- Section 6 contains information for servicing the instrument. This section includes information on fuse replacement, line voltage selection, calibration and troubleshooting.
- Section 7 contains replaceable parts information.

1.9 GETTING STARTED

The Model 199 System DMM is a highly sophisticated instrument with many capabilities. To get the instrument up and running quickly use the following procedure. For complete information on operating the Model 199 consult the appropriate section of this manual.

Power Up

1. Plug the line cord into the rear panel power jack and plug the other end of the cord into an appropriate, grounded power source. See paragraph 2.2.1 for more complete information.
2. Press in the POWER switch to apply power to the instrument. The instrument will power up in the 300V DC range.

Making Measurements

1. Connect the supplied safety shrouded test leads to the front panel VOLTS HI and LO input terminals. Make sure the INPUT switch on the front panel is in the front position.
2. To make a voltage measurement, simply connect the input leads to a DC voltage source (up to 300V) and take the reading from the display.
3. To change to a different measuring function, simply press the desired function button. For example, to measure resistance, press the OHMS button.

Using DMM Setup

Press SHIFT DMM SETUP, then use NEXT to scroll through selections. The following can be selected or viewed:

- Software revision
- Mux on/off
- IEEE-488 address
- Line frequency
- Save setup
- LED test
- Diagnostics
- Unit reset

For all selections except software revision and IEEE-488 address, use uprange/downrange to toggle the selection.

Paragraph 2.7 provides the detailed information for using DMM SETUP.

1.10 ACCESSORIES

The following accessories are available to enhance Model 199 capabilities.

Model 1651 50-Ampere Current Shunt—The Model 1651 is an external 0.001Ω ±1% 4-terminal shunt, which permits current measurements from 0 to 50A AC or DC.

Model 1681 Clip-On Test Lead Set—The Model 1681 contains two leads, 1.2m (4 ft.) long terminated with banana plugs and spring action clip probes.

Model 1682A RF Probe—The Model 1682A permits voltage measurements from 100kHz to 250MHz. AC to DC transfer accuracy is ±1dB from 100kHz to 250MHz at 1V, peak responding, calibrated in RMS of a sine wave.

Model 1685 Clamp-On AC Probe—The Model 1685 measures AC current by clamping on to a single conductor. Interruption of the circuit is unnecessary. The Model 1685 detects currents by sensing the changing magnetic field produced by the current flow.

Model 1751 Safety Test Leads—Finger guards and shrouded banana plugs help minimize the chance of making contact with live circuitry.

Model 1754 Universal Test Lead Kit—The Model 1754 is a 12 piece test lead kit, with interchangeable plug-in accessories. Included in the kit is one set of test leads (1-red, 1-black), two spade lugs, two standard banana plugs, two phone tips (0.06 DIA.), two hooks and miniature alligator clips (with boots).

Model 1992 4/8 Channel Scanner—The Model 1992 Scanner option allows scanning of four, 4-pole channels, or eight, 2-pole channels. The Model 1992 installs within the Model 199 with connections available on the rear panel of the instrument.

Model 1993 Quick Disconnect Scanner Connector Kit—The Model 1993 includes two connector blocks, 10 tie wraps, and two sets of red and black output cables for the Model 1992 Scanner Card.

Model 1998 Rack Mounting Kit—The Model 1998-1 Single Fixed Rack Mounting Kit mounts a single Model 199 in a standard 19 inch rack. The Model 1998-2 Dual Fixed Rack Mounting Kit mounts two Model 199s side by side in a standard 19 inch rack.

Model 5806 Kelvin Clip Lead Set—The Model 5806 includes two Kelvin clip test lead assemblies with banana plug termination (one red, one black). A set of eight replacement rubber bands for the Model 5806 is also available (Keithley P/N GA-22).

Model 7007 IEEE-488 Shielded Cables—The Model 7007 connects the Model 199 to the IEEE-488 bus using shielded cables to reduce electromagnetic interference (EMI). The Model 7007-1 is one meter in length and has a EMI shielded IEEE-488 connector at each end. The Model 7007-2 is identical to the Model 7007-1, but is two meters in length.

Model 7008 IEEE-488 Cables—The Model 7008 connects the Model 199 to the IEEE-488 bus. The Model 7008-3 is 0.9m (3 ft.) in length and has a standard IEEE-488 connector at each end. The Model 7008-6 cable is identical to the Model 7008-3, but is 1.8m (6 ft.) in length.

SECTION 2
Basic DMM Operation

2.1 INTRODUCTION

Operation of the Model 199 can be divided into two general categories: front panel operation and IEEE-488 bus operation. This section contains information necessary to use the instrument from the front panel. These functions can also be programmed over the IEEE-488 bus, as described in Section 3.

2.2 POWER UP PROCEDURE

2.2.1 Line Power

Use the following procedure to connect the Model 199 to line power and power up the instrument.

1. Check that the instrument is set to correspond to the available line power. When the instrument leaves the factory, the externally selected line voltage is marked on the rear panel. Ranges are 105V-125V or 210V-250V 50/60Hz AC (90-110V, 180-220V with optional transformer). If the line voltage setting of the instrument needs to be changed, set switch as required. If the line frequency setting of the instrument needs to be checked and/or changed, utilize front panel DMM SETUP (see paragraph 2.7) after the instrument completes the power up sequence (the line frequency is displayed upon power up).
2. Connect the female end of the power cord to the AC receptacle on the rear panel of the instrument. Connect the other end of the cord to a grounded AC outlet.

WARNING

The Model 199 is equipped with a 3-wire power cord that contains a separate ground wire and is designed to be used with grounded outlets. When proper connections are made, instrument chassis is connected to power line ground. Failure to use a grounded outlet may result in personal injury or death because of electric shock.

CAUTION

Be sure that the power line voltage agrees with the indicated range on the rear panel of the instrument. Failure to observe this precaution may result in instrument damage.

2.2.2 Power Up Sequence

The instrument can be turned on by pressing in the front panel POWER switch. The switch will be at the inner most position when the instrument is turned on. Upon power up, the instrument will do a number of tests on itself. Tests are performed on memory (ROM, RAM and E²PROM). If RAM or ROM fails, the instrument will lock up. If E²PROM FAILS, the message "UNCAL" will be displayed. See paragraph 6.7.2 for a complete description of the power up self test and recommendations to resolve failures.

Immediately upon power up, the unit will display the programmed line frequency. For example:

FREQ = 60HZ

2.2.3 Default Conditions

Default conditions can be defined as setup conditions that the instrument will return to when a particular feature or command is asserted. The Model 199 will return to either factory default conditions or user saved default conditions.

Factory Default Conditions

At the factory, the Model 199 is set up so that the instrument is configured to certain setup conditions on the initial power up. These factory default conditions are listed in Tables 2-1 and 3-7 (located in Section 3). If alternate setup conditions are saved (see User Saved Default Conditions), the instrument can be returned to the factory default conditions by using Reset, available under DMM SETUP. See paragraph 2.7.

Table 2-1. Factory Default Conditions

Control/Feature	Default Condition
Function*	DCV
Range*	300V
Resolution*	5½ Digits
Zero*	Off
dB*	Off
Filter*	Off
Multiplexer*	On
IEEE-488 Primary Address*	26
Line Frequency*	60Hz
Trigger Delay*	0msec
Reading Interval*	175msec (select off)
Trigger Mode*	Continuous
Data Store	Off
Poles†	2
Ratio†	Off
Scan Mode†	Manual

*These modes can be altered by using save setup.
†With optional 1992 scanner.

User Saved Default Conditions

Each function of the Model 199 "remembers" the last measurement configuration that it was set up for (such as range, zero value, etc). Switching back and forth between functions will not affect the unique configuration of each function. However, the instrument will "forget" the configurations on power-down unless they are saved (only one instrument configuration can be saved).

Unique setup conditions can be saved by using SAVE under DMM SETUP or by sending device-dependent command L1 over the IEEE-488 bus. These user saved default conditions will prevail over the factory default conditions on power-up, or when a DCL or SDC is asserted over the bus.

IEEE Address and Line Frequency

Any IEEE address and line frequency setting can be saved as default conditions by using the SAVE option under DMM SETUP or by sending L1 over the bus. See paragraph 2.7 for complete information on using DMM SETUP.

NOTE

An "UNCAL" error will set the IEEE address to 26 and the line frequency to 60Hz.

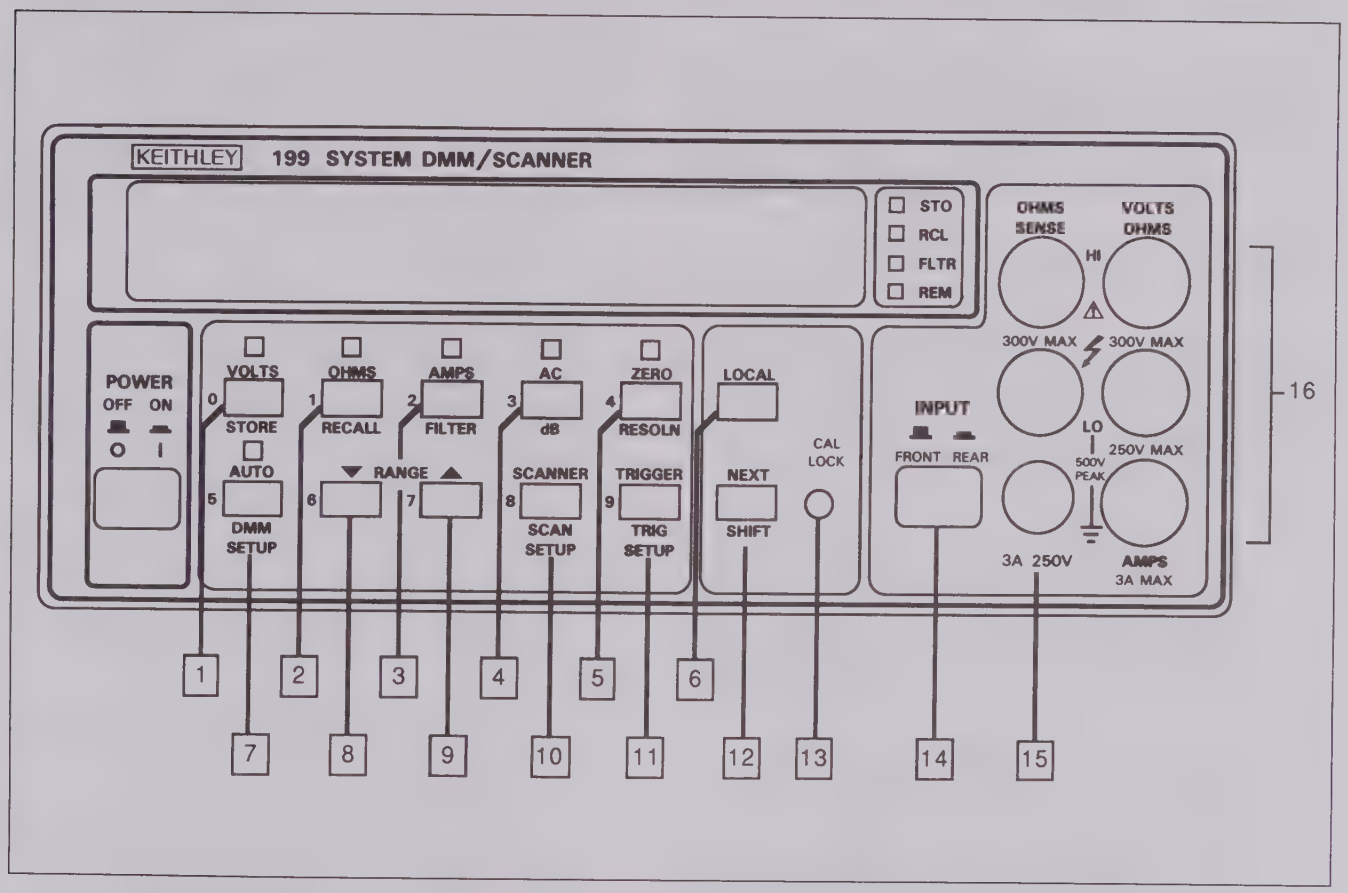


Figure 2-1. Model 199 Front Panel

2.3 FRONT PANEL FAMILIARIZATION

The front panel of the Model 199 is shown in Figure 2-1. The following paragraphs describe the various components of the front panel in detail.

2.3.1 Display and Indicators

Display—The 10-character alphanumeric LED display is used to display numeric data, range and functions mnemonics (for example, mV), as well as messages. When the optional Model 1992 Scanner is being used, the channel number is displayed in the right most digit.

Function Indicators—The indicator or indicators that are on identify the measurement function presently selected.

Range Indicator—The AUTO indicator will be on when autoranging is selected. Manual ranging is in effect when AUTO is off.

Zero Indicator—ZERO will be on when the zero mode is enabled. Zero is used to subtract a baseline value from the measured signal. ZERO will flash when zero has been enabled, but a reading that has yet to be triggered.

Filter Indicator—FLTR indicates when the running average filter is enabled. A flashing FLTR indicates the filter has not yet settled and shows the update rate.

Remote Indicator—REM shows when the Model 199 is in the IEEE-488 remote state. See Section 3 for more detailed IEEE-488 information.

Data Store Indicators—STO shows when the instrument is storing data in the data store buffer. RCL indicates that data store information is being displayed (RCL flashes when data store is full).

Display Update Indication—The decimal point in the right decimal point flashes to indicate the display update rate.

2.3.2 Power Switch

POWER controls AC line power to the instrument. Depressing and releasing the switch once turns the power on; depressing and releasing the switch a second time turns the power off. The on and off positions are marked on the front panel immediately above the POWER switch.

2.3.3 Controls

The main controls discussed below are all momentary-contact switches. These controls are numbered on Figure 2-1. Many of the controls have a secondary function that is selected by pressing SHIFT before pressing the control in question. SHIFTed controls are placed in parentheses in the following discussions.

[1] VOLTS/(STORE)—VOLTS places the instrument in the volts function. See paragraphs 2.6.4 and 2.6.7 for DCV and ACV measurement information. (STORE) allows access to the data store buffer to select buffer size and initate the storage of readings. A third function of this key is to enter the number 0 for some numeric input operations.

[2] OHMS/(RECALL)—OHMS selects the resistance measurement function, as discussed in paragraph 2.6.6. (RECALL) allows you to display data store buffer information on the front panel display. A third function of this key is to enter the number 1 for numeric input operations.

[3] AMPS/(FILTER)—The AMPS buttons select current measurement, as discussed in paragraph 2.6.8. (FILTER) toggles the filter between internal and user filter (FLTR on for user). See paragraph 2.6.3 for details on filter operation. The third function of this key is to enter the number 2 when numeric input is required.

[4] AC/(dB)—AC selects AC volts or AC current measurement, depending on whether VOLTS or AMPS is in effect. (dB) toggles the dB function on or off for AC voltage or current measurements. 0dB reference for these functions is 1V (volts) or 1mA (amps). Paragraph 2.6.9 gives more information on dB measurements. The third function of this key is to enter the number 3 for numeric inputs.

[5] ZERO/(RESOLN)—ZERO enables the zero mode, which allows baseline values to be subtracted from subsequent measurements, and can also be used for zero correction (paragraph 2.6.2). (RESOLN) toggles the display between 4½ digit and 5½ digit resolution. The third function for this key is to enter the number 4 when numeric input is required.

[6] LOCAL—The LOCAL key takes the instrument out of remote when it is being used over the IEEE-488 bus. Note that all other control keys will be locked out when the unit is in remote (LOCAL will also be inoperative when LLO is in effect).

[7] AUTO/(DMM SETUP)—AUTO places the instrument in autoranging, which is available for all ranges and functions. While in autoranging, the unit will go to the best range to measure the applied signal. Autoranging can be cancelled by pressing AUTO or one of the two manual ranging buttons (discussed below). (DMM SETUP) allows access to the following functions: software revision level, multiplexer on/off, IEEE-488 primary address programming, 50/60Hz line frequency selection, save setup, LED test, debug, and instrument reset (see paragraph 2.7). Entering the number 5 is the third function of this key.

[8] Downrange (▼)—decrements the range and also cancels autorange if selected. The secondary function of this key is to enter the number 6.

[9] Uprange (▲)—increments the range and also cancels autorange if selected. The secondary function of this key is to enter the number 7.

[10] SCANNER/(SCAN SETUP)— SCANNER allows you to select the scanner channel limit and scanner channel number. (SCAN SETUP) allows you to program 2/4 pole operation, ratio, and scanner trigger mode. See paragraph 2.11 for more scanner information. The third function of this key is to enter the number 8 for numeric input operations.

[11] TRIGGER/(TRIG SETUP)—TRIGGER triggers instrument readings. (TRIG SETUP) allows you to select the trigger mode, delay, and interval. The default delay is 0msec, and the default interval is 175msec. See paragraphs 2.8 and 2.9 for more information on triggering. A third function of this key is to enter the number 9.

[12] SHIFT/NEXT—SHIFT allows access to secondary functions of many of the control keys (for example, DMM SETUP). NEXT scrolls through menu selections for those functions with menus.

2.3.4 CAL LOCK Switch [13]

The CAL LOCK switch disables calibration from the front panel or over the IEEE-488 bus. Before the unit can be calibrated, this switch must be enabled. See paragraph 6.4 for more calibration information.

2.3.5 INPUT Switch [14]

The front panel INPUT switch selects between the front and rear panel input terminals. Front panel terminals are selected with the switch out, while rear-panel terminals are selected with the switch in. The switch positions are marked immediately above the switch on the front panel.

2.3.6 Current Input Fuse [15]

The current input fuse is a 3A normal blow fuse that protects the AMPS input from excessive current. See paragraph 6.3 for fuse replacement procedures.

2.3.7 Input Terminals [16]

The input terminals are intended to be used with safety shrouded test leads to help minimize the possibility of contact with live circuits. Note that all the terminals except AMPS are duplicated on the rear panel. The front panel INPUT switch determines which set of terminals is active.

VOLTS OHMS HI and LO—The VOLTS OHMS HI and LO terminals are used for making DC volts, AC volts, and two-wire resistance measurements.

AMPS—AMPS is used in conjunction with LO to make DC current and AC current measurements.

OHMS SENSE HI and LO—These terminals are used with VOLTS OHMS HI and LO to make four-wire resistance measurements.

2.4 REAR PANEL FAMILIARIZATION

The rear panel of the Model 199 is shown in Figure 2-2. The various items located on the rear panel are discussed in the following paragraphs.

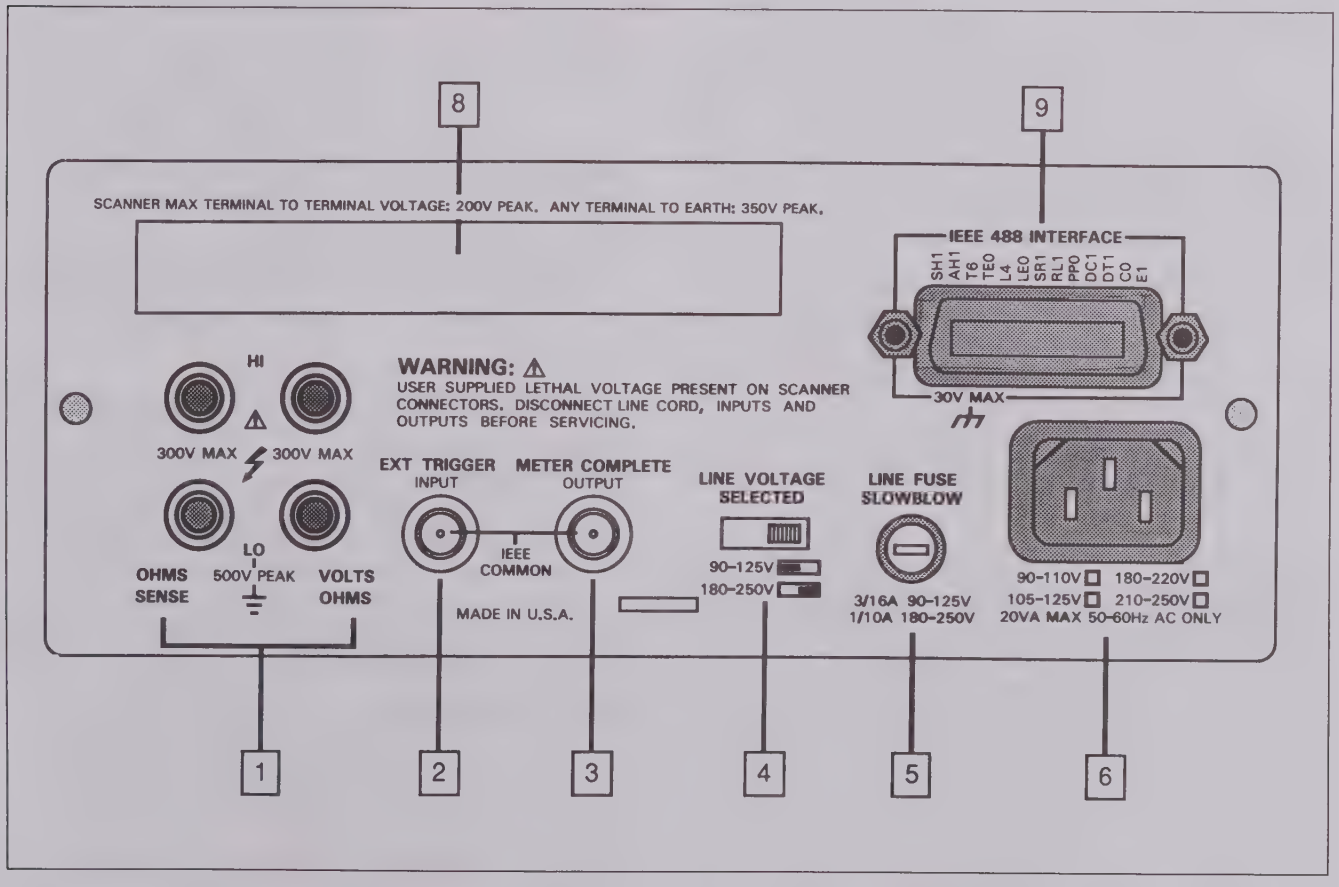


Figure 2-2. Model 199 Rear Panel

2.4.1 Connectors and Terminals

[1] Input terminals—The rear panel VOLTS OHMS and OHMS SENSE terminals perform the same functions as the equivalent front panel terminals. Voltage and two-wire resistance measurements are made using the VOLTS OHMS terminals, while four-wire resistance measurements are made using both the OHMS SENSE and VOLTS OHMS terminals.

[2] EXTERNAL TRIGGER INPUT—This BNC connector is used to apply negative-going, TTL-compatible trigger pulses to take one or more readings depending on the selected trigger mode. See paragraph 2.9 for additional information.

[3] VOLTMETER COMPLETE OUTPUT—This BNC output connector provides a TTL-compatible, negative-going pulse when the Model 199 has completed a reading. It can be used to trigger other instruments, as discussed in paragraph 2.9.

2.4.2 Line Voltage Aspects

[4] Line Voltage Selection Switch—This switch selects the operating line voltage of the instrument. Before operation, be sure the switch is in the correct position for the line voltage in your area.

[5] LINE FUSE—The line fuse provides protection for the AC power line input. Refer to paragraph 6.3 for fuse replacement procedures.

[6] LINE VOLTAGE receptacle—Power is applied to the instrument through the supplied power cord to the three-terminal, grounded AC receptacle. Note that the selected supply voltage is marked on the rear panel below the receptacle.

2.4.3 IEEE-488 Connector [7]

The IEEE-488 connector is used to interface the Model 199 to the IEEE-488 bus. IEEE-488 interface functions are marked immediately above the connector. Refer to Section 3 for detailed IEEE-488 information.

2.4.4 Scanner Card Slot [8]

The optional Model 1992 Scanner Card installs in this slot. Refer to paragraphs 2.11 and 3.12 for scanner operation and programming information. Section 6 contains scanner installation procedures.

2.5 DISPLAY MESSAGES

Table 2-2 lists and explains the various display messages associated with front panel operation of the Model 199.

Table 2-2. Error Messages

Message	Explanation
UNCAL	E²PROM failure on power up. See paragraph 6.7.2.
NO FUNC	No shifted function.
O.VERFL KΩ	Overrange-Decimal point position and mnemonics define function and range (3kΩ range shown). The number of characters in the "OVERFL" message defines the display resolution (5½d resolution shown).
TRIGGER OVERRUN	Trigger received while still processing reading from last trigger.
AC ONLY	Selecting dB with instrument not in ACV or ACA.
NO RANGE	Pressing a range button while in ACV dB or ACA dB.
CONFLICT	Improper state when calibrating (i.e., dB).
INTERVAL OVERRUN	Interval too short.
NO DATA	No data store data
NO SCANNER	Scanner not installed
CAL LOCKED	Calibration locked out
CHAN 4 MAX	Channel limit is 4 in 4-pole mode*
CHAN 8 MAX	Channel limit is 8 in 2-pole mode*

*With optional scanner

2.6 BASIC MEASUREMENTS

The following paragraphs describe the basic procedures for making voltage, resistance, current, and dB measurements.

High Energy Circuit Safety Precautions

To optimize safety when measuring voltage in high energy distribution circuits, read and use the directions in the following warning.

WARNING

Dangerous arcs of an explosive nature in a high energy circuit can cause severe personal injury or death. If the meter is connected to a high energy circuit when set to a current range, low resistance range or any other low impedance range, the circuit is virtually shorted. Dangerous arcing can also result when the meter is set to a voltage range if the minimum voltage spacing is reduced.

When making measurements in high energy circuits use test leads that meet the following requirements:

- Test leads should be fully insulated.
- Only use test leads that can be connected to the circuit (e.g. alligator clips, spade lugs, etc.) for hands-off measurements.
- Do not use test leads that decrease voltage spacing. This diminishes arc protection and creates a hazardous condition.

Use the following sequence when testing power circuits:

1. De-energize the circuit using the regular installed connect-disconnect device such as the circuit breaker, main switch, etc.
2. Attach the test leads to the circuit under test. Use appropriate safety rated leads for this application.
3. Set the DMM to the proper function and range.
4. Energize the circuit using the installed connect-disconnect device and make measurements without disconnecting the DMM.
5. De-energize the circuit using the installed connect-disconnect device.
6. Disconnect the test leads from the circuit under test.

CAUTION

The maximum common-mode input voltage (the voltage between input LO and chassis ground) is 500V peak. Exceeding this value may damage the instrument.

2.6.1 Warm Up Period

The Model 199 is usable immediately when it is first turned on. However, the instrument must be allowed to warm up for at least two hours to achieve rated accuracy.

2.6.2 Zero

The zero feature serves as a means of baseline suppression by allowing a stored offset value to be subtracted from subsequent readings. When the ZERO button is pressed, the instrument takes the currently displayed reading as a baseline value. All subsequent readings represent the difference between the applied signal level and the stored baseline.

A baseline level can be established for any or all measurement functions and is remembered by each function. For example, a 10V baseline can be established on DCV, a 5V baseline can be established on ACV and a 10kΩ baseline can be established on OHMS at the same time. These levels will not be cancelled by switching back and forth between functions. Once a baseline is established for a measurement function, that stored level will be the same regardless of what range the Model 199 is on. For example, if 1V is established as the baseline on the 3V range, then the baseline will also be 1V on the 30V through 300V ranges. A zero baseline level can be as large as full range.

NOTE

The following discussion on dynamic range is based on a display resolution of 5½ digits. At 4½d resolution, the number of counts would be reduced by a factor of 10.

By design, the dynamic measurement range of the Model 199, at 5½-digit resolution, is 606,000 counts. With zero disabled, the displayed reading range of the instrument is ±303,000 counts. With zero enabled, the Model 199 has the capability to display ±606,000 counts. This increased display range ensures that the dynamic measurement range of the instrument is not reduced when using a zero

baseline value. The following two examples will use the maximum allowable zero values (303,000 counts and −303,000 counts) to show that dynamic measurement range will not be reduced. It is important to note that the increased display range does not increase the maximum allowable input level to the instrument. For example, on the 3V range, the Model 199 will always overrange when more than ±3.03V is connected to the input.

Example 1—The instrument is set to the 3V DC range and a maximum −3.03000V is established as the zero value. When −3.03000V is connected to the input of the Model 199, the display will read 0.00000V. When +3.03000V is connected to the input, the display will read +6.06000V. Thus, the dynamic measurement range of the Model 199 is 0V to 6.06V, which is 606,000 counts.

Example 2—The instrument is still set to the 3V DC range, but a maximum +3.03000V is the zero level. When +3.03000V is connected to the input of the Model 199, the display will read 0.00000V. When −3.03000V is connected to the input, the display will read −6.06000V. Thus the dynamic measurement range of the instrument is −6.06V to 0V, which is still 606,000 counts.

Zero Correction—The Model 199 must be properly zeroed when using the 300mV DC or the 300Ω range in order to achieve rated accuracy specifications. This procedure should be performed whenever the ambient temperature changes. To use ZERO for zero correction, perform the following steps:

1. Disable zero, if presently enabled, by pressing the ZERO button. The ZERO indicator will turn off.
2. Select the 300mV DC or the 300Ω range.
3. Connect the test leads to the input of the Model 199 and short them together. If four-wire resistance measurements are to be made, connect and short all four leads together. Allow any thermals to stabilize.

   Note: At 5½-digit resolution, low level measurement techniques need to be employed. Use Kelvin test leads or shielded test leads. See paragraph 2.6.5 for low level measurement considerations.
4. Press the ZERO button. The display will read zero.
5. Remove the short and connect the test leads to the signal or resistance to be measured.

   Note: Test lead resistance (2-wire) is also compensated for when zeroing the 300Ω range with the above procedure.

Baseline Levels—Baseline values can be established by applying baseline levels to the instrument. To establish a baseline level by applying a level to the Model 199, perform the following steps:

1. Disable zero, if presently enabled, by pressing the ZERO button. The ZERO indicator will turn off.
2. Select a function and range that is appropriate for the anticipated measurement.
3. Connect the desired baseline level to the input of the Model 199 and note that level on the display.
4. Press the ZERO button. The display will zero and the ZERO indicator will be enabled. The previously displayed reading will be the stored baseline.

WARNING

With ZERO enabled, a hazardous voltage baseline level (±40V or more), not displayed, may be present on the input terminals. If not sure what is applied to the input, assume that a hazardous voltage is present.

5. Disconnect the stored signal from the input and connect the signal to be measured in its place. Subsequent readings will be the difference between the stored value and the applied signal.

Notes:

1. Disabling zero cancels the zero baseline value on that selected function. Baselines established on other functions are not affected.
2. To store a new baseline on a selected function, zero must first be disabled and then enabled again. The new value will be stored with the first triggered conversion.
3. Setting the range lower than the suppressed value will overrange the display; the instrument will display the overflow message under these conditions.
4. When the ZERO button is pressed to enable zero, the ZERO indicator light will blink until an on scale reading is available to use as a zero level. In the one-shot trigger mode, the unit must be triggered to store the zero value.

2.6.3 Filter and Resolution

The following paragraphs discuss the internal running average filter and the 4½ and 5½ digit resolution modes of the Model 199.

Filter

The Model 199 uses two running average filters in order to reduce reading noise. The two filters include the internal filter and the front panel filter, as described below.

When the front panel FLTR light is off, the internal filter is enabled, and the number of integrations per reading averaged depends on the selected range and function, as indicated below.

Function	Range	Window (Counts)	#Integrations Averaged Per Reading
DCV	300mV	6	11
DCV	3V-300V	3	6
ACV	All	None	None
Ohms	300Ω-30kΩ	4	6
Ohms	300kΩ	10	11
Ohms	3MΩ	40	11
Ohms	30MΩ-300MΩ	400	31
DCA	All	6	11
ACA	All	None	None
dBV		None	None
dBA		None	None

In order to speed up response to large signal steps changes, the Model 199 uses a "window" around the displayed average. As long as the readings are within this window, the displayed value is based on the average of the most recent number of integrations. If a new integration is outside this window, the displayed value will be the new reading, and new averaging will start from this point. The window value for the internal filter also depends on the range and function (see above).

The front panel filter is enabled when the front panel FLTR indicator is on. The front panel filter uses a fixed window of 1000 counts with 30 readings averaged per reading on all ranges and functions.

NOTES:

1. In a continuous trigger mode, the FLTR indicator will flash until the filter is settled. Readings will continue to update the display while the filter is settling, but the display will not represent the final, filtered reading value until FLTR stops flashing (when the proper number of readings have been averaged).
2. In a one-shot trigger mode, no readings will be displayed or transmitted over the IEEE-488 bus until the filter has settled. Each trigger clears the filter, fills the filter with new readings, and then issues a METER complete pulse once the reading is available. Therefore, filtered one-shot times can be long.
3. The filter can be turned off entirely by sending the P0X command over the IEEE-488 bus; see paragraph 3.9.

Resolution

The Model 199 can be operated with either 4½ or 5½ digits of display resolution. In the 4½-digit mode, the instrument displays ±30,300 counts, while ±303,000 counts are displayed in the 5½-digit mode. The resolution can be programmed separately for each of the five measuring functions.

NOTE

On the 300kΩ and higher resistance ranges, only 5½-digit resolution is available.

To change display resolution press SHIFT RESOLN. The display will toggle to the opposite resolution each time you perform this keystroke sequence. Note that changing the resolution restarts the filter; the instrument will display dashes after changing resolution until a new reading is available for display.

The integration period of the A/D converter is 2.59msec in the 4½-digit mode, while line cycle integration (20msec, 50Hz; 16.67msec, 60HZ) is used for 5½-digits. Thus the selected resolution affects the overall reading rate (as does the selected function and amount of filtering).

2.6.4 DC Voltage Measurements

The Model 199 can be used to make DC voltage measurements in the range of ±1μV to ±300V. Use the following procedures to make DC voltage measurements.

CAUTION

The maximum input voltage between the HI and LO terminals is 425V peak or 300V RMS whichever is less. Exceeding this value may cause instrument damage.

1. Select the DC volts function by pressing the VOLTS button.
2. Select a range consistent with the expected voltage or use autorange.
3. Select the front or rear panel input terminals with the INPUT switch.

NOTE

The 300mV DC range requires zero to be set in order to achieve rated accuracy. The zero correction procedure can be found in paragraph 2.6.2.

4. Connect the signal to be measured to the selected input terminals as shown in Figure 2-3.
5. Take the reading from the display.

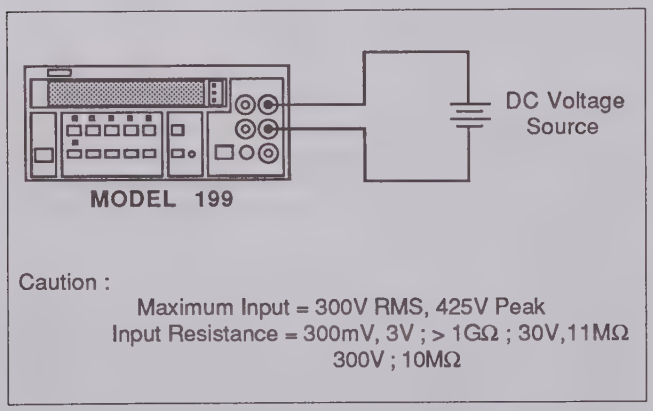


Figure 2-3. DC Voltage Measurements

2.6.5 Low-Level Measurement Considerations

Accuracy Considerations—For sensitive measurements, other external considerations besides the Model 199 will affect the accuracy. Effects not noticeable when working with higher voltages are significant in microvolt signals. The Model 199 reads only the signal received at its input; therefore, it is important that this signal be properly transmitted from the source. The following paragraphs indicate factors which affect accuracy, including thermal emfs and stray pick-up.

Shielding—AC voltages which are extremely large compared with the DC signal may erroneously produce a DC output. Therefore, if there is AC interference, the circuit should be shielded with the shield connected to the Model 199 input LO (particularly for low-level sources). Improper shielding can cause the Model 199 to behave in one or more of the following ways:

1. Unexpected offset voltages.
2. Inconsistent readings between ranges.
3. Sudden shifts in reading.

To minimize pick-up, keep the voltage source and the Model 199 away from strong AC magnetic sources. The voltage induced due to magnetic flux is proportional to the area of the loop formed by the input leads. Therefore, minimize the loop area of the input leads and connect each signal at only one point.

Thermal EMFs—Thermal emfs (thermoelectric potentials) are generated by thermal differences between the junction of dissimilar metals. These can be large compared to the signal which the Model 199 can measure. Thermal emfs can cause the following problems:

1. Instability or zero offset is much higher than expected.
2. The reading is sensitive to (and responds to) temperature changes. This effect can be demonstrated by touching the circuit, by placing a heat source near the circuit or by a regular pattern of instability (corresponding to heating and air-conditioning systems or changes in sunlight).
3. To minimize the drift caused by thermal emfs, use copper leads to connect the circuit to the Model 199. A banana plug is generally suitable and generates just a few microvolts. A clean copper conductor such as #10 bus wire is about the best for this application. The leads to the input may be shielded or unshielded, as necessary. Refer to Shielding.
4. Widely varying temperatures within the circuit can also create thermal emfs. Therefore, maintain constant temperatures to minimize these thermal emfs. A cardboard box around the circuit under test also helps by minimizing air currents.
5. The ZERO control can be used to null out constant offset voltages.
6. Additional thermals may be generated by the optional Model 1992 Scanner.

2.6.6 Resistance Measurements

The Model 199 can make resistance measurements from 1mΩ to 300MΩ. The Model 199 provides automatic selection of 2-terminal or 4-terminal resistance measurements. This means that if the ohms sense leads are not connected, the measurement is done 2-terminal. If the sense leads are connected, the measurement is done 4-terminal. For 4-terminal measurements, rated accuracy can be obtained as long as the maximum lead resistance does not exceed the values listed in Table 2-3. For best results on the 300Ω, 3kΩ and 30kΩ ranges, it is recommended that 4-terminal measurements be made to eliminate errors caused by the voltage drop across the test leads which will occur when 2-terminal measurements are made. The Model 5806 Kelvin Test Lead Set is ideal for low resistance 4-terminal measurements. In the 4½ digit mode, use 4-terminal or connect the source leads to the sense leads at the instrument to avoid extra noise pickup.

To make resistance measurements, proceed as follows:

1. Select the ohms function by pressing the OHMS button.
2. Select a range consistent with the expected resistance or use autorange.
3. Select the front or rear panel input terminals using the INPUT switch.
4. For 2-terminal measurements connect the resistance to the instrument as shown in Figure 2-4. For 4-terminal measurements connect the resistance to the instrument as shown in Figure 2-5.
5. Take the reading from the display.

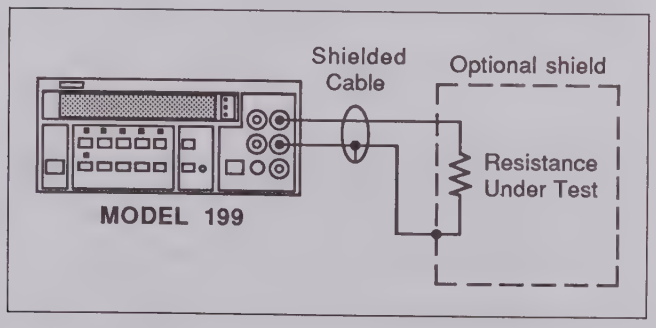


Figure 2-4. Two-Terminal Resistance Measurements

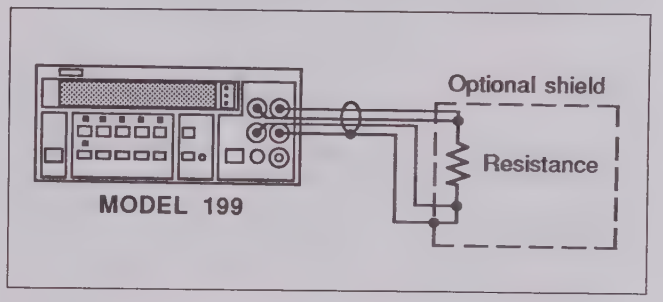


Figure 2-5. Four-Terminal Resistance Measurements

Notes:

1. Table 2-3 shows the current output for each resistance range.
2. It helps to shield resistance greater than 100kΩ (or anytime 4½ digit resolution is used) to achieve a stable reading. Place the resistance in a shielded enclosure and electrically connect the shield to the LO input terminal of the instrument.
3. Diode Test—The 3kΩ range can be used to test diodes as follows:
   A. Select the 3kΩ range.
   B. Forward bias the diode by connecting the red terminal of the Model 199 to the diode anode. A good diode will typically measure between 300Ω and 1kΩ.
   C. Reverse bias the diode by reversing the connections on the diode. A good diode will overrange the display.

Table 2-3. Resistance Ranges

Range	5½d Resolution	Nominal I-Short	Maximum Test Lead Resistance (Ω) for <1 Count Error (5½d)
300 Ω	1mΩ	1.7mA	10
3kΩ	10mΩ	1.7mA	30
30 kΩ	100mΩ	160μA	100
300 kΩ	1 Ω	50μA	300
3MΩ	10 Ω	5μA	1k
30MΩ	100 Ω	0.5μA	3k
300MΩ	1 kΩ	0.5μA	30k

NOTE: Typical open circuit voltage is 5.5V.

2.6.7 TRMS AC Voltage Measurements

The instrument can make TRMS AC voltage measurements from 1μV to 300V. To measure AC volts, proceed as follows:

1. Select the AC volts function by pressing the VOLTS and AC buttons.
2. Select a range consistent with the expected voltage or use autorange.
3. Select the front or rear panel input terminals using the INPUT switch.

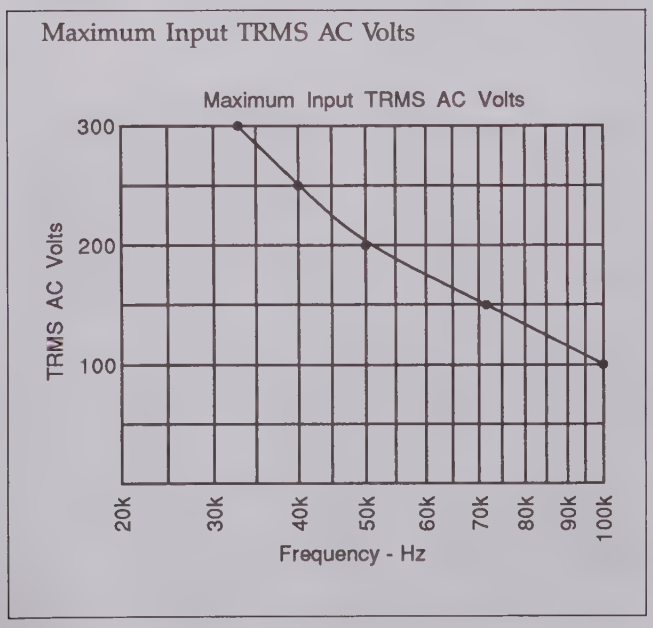
NOTE

There is a small amount of offset (typically 150 counts at 5½d) present when using the ACV function. Do not zero this level out. Paragraph 2.6.10 provides an explanation of AC voltage offset.

4. Connect the signal to be measured to the selected input terminals as shown in Figure 2-6.
5. Take the reading from the display.

Clarifications of TRMS ACV Specifications:

Maximum Allowable Input—The following graph summarizes the maximum input based on the 10^7V•Hz specification.



Settling Time—1sec to within 0.1% of change in reading. This time specification does not include A/D conversion time.

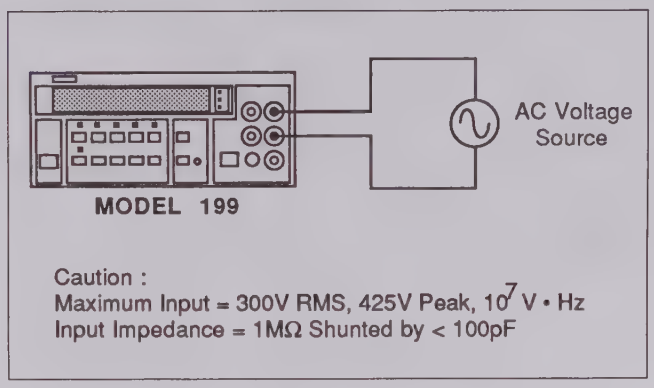


Figure 2-6. TRMS AC Voltage Measurement

2.6.8 Current Measurements (DC or TRMS AC)

The Model 199 can make DC or TRMS AC current measurements from 100nA (at 5½d resolution) to 3A. Use the following procedure to make current measurements.

1. Select the DC current or AC current function by pressing the AMPS button (also press AC for AC current).
2. Select a range consistent with the expected current or use autorange.
3. Connect the signal to be measured to the front-panel input terminals as shown in Figure 2-7.
4. Take the reading from the display.

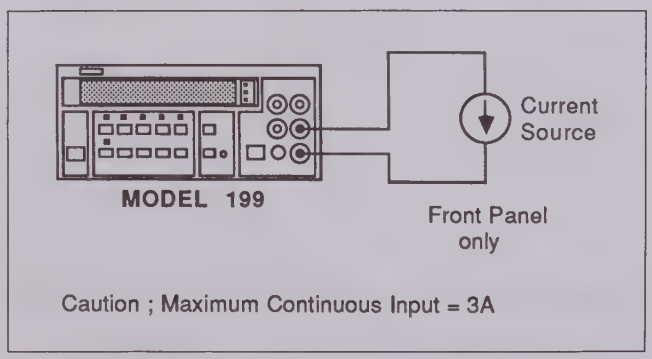


Figure 2-7. Current Measurements

2.6.9 dB Measurements

The dB measurement mode makes it possible to compress a large range of measurements into a much smaller scope. AC dB measurements can be made with the instrument in the ACV or ACA function. The relationship between dB and voltage and current, can be expressed by the following equations:

$$dB = 20 \log \left(\frac{V_{in}}{V_{ref}} \right)$$

$$dB = 20 \log \left(\frac{I_{in}}{I_{ref}} \right)$$

In ACV, the instrument will read 0dB when 1V is applied to the input. With ACA dB selected, the instrument will read 0dB when 1mA is applied to the input.

Reference levels other than 1V and 1mA cannot be directly programmed, but they can be established with the zero feature. This procedure simply consists of applying a signal to the instrument and pressing the ZERO button. That suppressed level is the dB reference (0dB point).

The following procedure explains how to use the zero feature to establish a reference:

1. Apply a voltage or current signal, that is to be used as the dB reference, to the input of the Model 199.
2. Press the ZERO button. The ZERO indicator will turn on and the display will zero. The reference is now whatever the applied signal is.
3. Disconnect the signal from the instrument.

AC dB Measurements—Perform the following steps to make dB measurements:

1. Select the AC volts or AC amps function. (Press VOLT or AMPS, then AC).
2. Select the front or rear panel input terminals with the INPUT switch.
3. Check and/or change the dB reference as previously explained.
4. Connect the signal to be measured to the input of the Model 199.
5. Enable the dB measurement mode by pressing SHIFT dB.
6. Take the dB reading from the display.

WARNING

With dB enabled, a hazardous voltage baseline level (±40V or more), not displayed, may be present on the input terminals. If not sure what is applied to the input, assume that a hazardous voltage is present.

dBm Measurements—dBm is defined as decibels above or below a 1mW reference. dB measurements can be made in terms of impedance rather than voltage or current. Because the instrument cannot directly establish impedance references, a voltage reference must be calculated and established for a particular impedance reference. Use the following equation to calculate the voltage reference needed for a particular impedance reference:

For 0dBm, $V_{ref} = \sqrt{1mW \bullet Z_{ref}}$

Example: Calculate the voltage reference needed to make dBm measurements referenced to 600Ω.

For 0dBm, $V_{ref} = \sqrt{0.001W \bullet 600\Omega}$

$= \sqrt{.6}$

$= .77456V$

Once the necessary voltage reference is known, it can be established in the Model 199 with the dB program. Subsequent dBm readings will be referenced to the corresponding impedance reference. Table 2-4 lists the voltage references needed for some commonly used impedance references.

dBW Measurements—dBW is defined as decibels above or below a 1W reference. dBW measurements are made in the same manner as dBm measurements; that is, calculate the voltage reference for a particular impedance and set the instrument to it with the dB program. The only difference between dBm and dBW is the reference point; 1mW vs 1W. The following equation can be used to calculate the voltage reference:

For 0dBW, $V_{ref} = \sqrt{1W \bullet Z_{ref}}$

Table 2-4. Corresponding Voltage Reference Levels for Impedance References

Reference Impedance (Ω)	Reference Voltage Level for: 0dBm	0dBW
8	0.0894	2.828
50	0.2236	
75	0.2739	
150	0.3873	
300	0.5477	
600	0.7746	
1000	1.0000	

V_{ref} for 0dBm = $\sqrt{10^{-3}W \bullet Z_{REF}}$

V_{ref} for 0dBW = $\sqrt{Z_{REF}}$

2.6.10 TRMS Considerations

Most DMMs actually measure the average value of an input waveform but are calibrated to read its RMS equivalent. This poses no problems as long as the waveform being measured is a pure, low-distortion sine wave. For complex, nonsinusodial waveforms, however, measurements made with an averaging type meter can be grossly inaccurate. Because of its TRMS measuring capabilities, the Model 199 provides accurate AC measurements for a wide variety of AC input waveforms.

TRMS Measurement Comparison—The RMS value of a pure sine wave is equal to 0.707 times its peak value. The average value of such a waveform is 0.637 times the peak value. Thus, for an average-responding meter, a correction factor must be designed in. This correction factor, K can be found by dividing the RMS valued by the average value as follows:

$$K = 0.707 / 0.637$$
$$= 1.11$$

By applying this correction factor to an averaged reading, a typical meter can be designed to give the RMS equivalent. This works fine as long as the waveform is a pure sine, but the ratios between the RMS and average values of different waveforms is far from constant, and can vary considerably.

Table 2-5 shows a comparison of common types of waveforms. For reference, the first waveform is an ordinary sine wave with a peak amplitude of 10V. The average value of the voltage is 6.37V, while its RMS value is 7.07V. If we apply the 1.11 correction factor to the average reading, it can be seen that both meters will give the same reading, resulting is no error in the average-type meter reading.

The situation changes with the half-wave rectified sine wave. As before, the peak value of the waveform is 10V, but the average value drops to 3.18V. The RMS value of this waveform is 3.86V, but the average responding meter will give a reading of 3.53V (3.18 x 1.11), creating an error of 11%.

A similar situation exists for the rectified square wave, which has an average value of 5V and an RMS value of 5.0V. The average responding meter gives a TRMS reading of 5.55V (5 × 1.11), while the Model 199 gives a TRMS reading of 5V. Other waveform comparisons can be found in Table 2-5.

AC Voltage Offset—The Model 199, at 5½d resolution, will typically display 150 counts of offset on AC volts with the input shorted. This offset is caused by the offset of the TRMS converter. This offset will not affect reading accuracy and should not be zeroed out using the zero feature. The following equation expresses how this offset (V_{offset}) is added to the signal input (V_{in}):

$$\text{Displayed reading} = \sqrt{(V_{in})^2 + (V_{offset})^2}$$

Example: Range = 2VAC
Offset = 150 counts (1.5mV)
Input = 200mV RMS

$$\text{Display reading} = \sqrt{(200mV)^2 + (1.5mV)^2}$$
$$= \sqrt{0.04V + (2.25 \times 10^{-6}V)}$$
$$= .200005V$$

The offset is seen as the last digit which is not displayed. Therefore, the offset is negligible. If the zero feature were used to zero the display, the 150 counts of offset would be subtracted from V_{in} resulting in an error of 150 counts in the displayed reading.

Crest Factor—The crest factor of a waveform is the ratio of its peak value to its RMS value. Thus, the crest factor specifies the dynamic range of a TRMS instrument. For sinusoidal waveforms, the crest factor is 1.414. For a symmetrical square wave, the crest factor is unity.

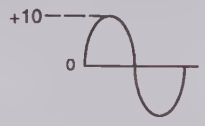
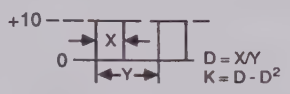
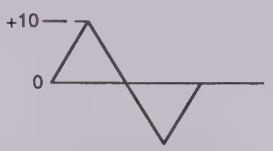
The crest factor of other waveforms will, of course, depend on the waveform in question because the ratio of peak to RMS value will vary. For example, the crest factor of a pulse is computed as follows:

$$CF = \sqrt{\frac{T}{t}}$$

Where T = period
t = pulse width

This relationship holds for all pulse waveforms.

Table 2-5. Comparison of Average and TRMS Meter Readings

Waveform	AC Coupled Peak Value	RMS Value	Average Responding Meter Reading	AC Coupled TRMS Meter Reading	Averaging Meter Percent Error
Sine 	10V	7.07V	7.07V	7.07V	0%
Half-Wave Rectified Sine	10V	3.86V	3.90V	3.86V	1%
Full-Wave Rectified Sine	10V	3.08V	2.98V	3.08V	3.2%
Square	10V	10.00V	11.10V	10.00V	11%
Rectified Square Wave	10V	5.00V	5.55V	5.00V	11%
Rectangular Pulse 	10V	$10 \bullet \sqrt{K}$	22.2K	$10 \bullet \sqrt{K}$	$\left[\frac{2.22K^{3/2} - K}{K}\right] \times 100$
Triangular Sawtooth 	10V	5.77V	5.55V	5.77V	4%

2.6.11 dB Applications

Measuring Circuit Gain/Loss—Any point in a circuit can be established as the 0dB point. Measurements in that circuit are then referenced to that point expressed in terms of gain (+dB) or loss (−dB). To set the zero dB point proceed as follows:

1. Place the Model 199 in AC volts and dB.
2. Connect the Model 199 to the desired location in the circuit.
3. Press the ZERO button. The display will read 0dB.
4. Gain/loss measurements can now be made referenced to the 0dB point.

Measuring Bandwidth—The Model 199 can be used to determine the bandwidth of an amplifier as follows:

1. Connect a signal generator and a frequency counter to the input of the amplifier.
2. Set the Model 199 to AC volts and autorange.
3. Connect the Model 199 to the load of the amplifier.
4. Adjust the frequency of the signal generator until a peak AC voltage reading is measured on the Model 199. This is the center frequency.
5. Press SHIFT dB button and then press the ZERO button. The 0dB point is now established.
6. Increase the frequency input until the Model 199 reads −3.00dB. The frequency measured on the frequency counter is the high-end limit of the bandwidth.
7. Decrease the frequency input until the dB reading again falls to −3.00dB. The frequency measured on the signal generator is the low-end limit of the bandwidth.

   Note: The bandwidth of the Model 199 is typically 300kHz. Do not use this application to check amplifiers that exceed the bandwidth of the Model 199.

Determining Q—The Q of a tuned circuit can be determined as follows:

1. Determine the center frequency and bandwidth as explained in the previous application (Measuring Bandwidth).
2. Calculate Q by using the following formula:

   Q = Center Frequency/Bandwidth

2.7 DMM SETUP PROGRAMS

There are eight DMM setup programs available from the front panel of the Model 199, as summarized in Table 2-6. These programs are described in detail in the following paragraphs.

Program Selection—Programs can be selected by pressing SHIFT DMM SETUP on the front panel. To scroll through programs, press the NEXT key. Once the desired program is displayed, perform the necessary operation, as described below.

Data Entry—The IEEE-488 primary address program requires numeric data entry. To enter data, use the data entry keys (0-9). The cursor location for data entry is indicated by the bright, flashing display digit. The cursor moves right each time a number is entered. The cursor will wrap around to the left after exiting the right most digit. When the desired value is displayed, press SHIFT to program the value.

Alternate Condition Selection—Most DMM setup programs have alternate conditions that can be selected. To toggle the conditions, press uprange or downrange to alternate between the the two selections.

Exiting DMM Setup—To exit DMM setups, repeatedly press NEXT and scroll through the complete list in the menu.

Table 2-6. DMM Setup Programs

Program Description	Display Message Upon Entry
Software revision level	REV.A0.66**
Multiplexer on/off	MUX ON
IEEE Primary Address	26 IEEE*
Line frequency (50 or 60Hz)	FREQ=60Hz*
Save instrument setups	SAVE NO
LED Test	LEDS OFF
Diagnostics	DEBUG OFF
Reset instrument	RESET NO

*Factory default values shown. 60Hz is default in the U.S. only

**Revision level may vary.

2.7.1 Software Revision Level

Upon entry to the DMM setup programs, the instrument will briefly display the software revision level presently installed in the unit, as in the example below:

REV.A0.66

2.7.2 Multiplexer, Auto Zero/Cal

The multiplexer auto/cal routines may be defeated by selecting this option under DMM setups. Using the Model 199 with auto zero/cal defeated has two main advantages: (1) increased measurement speed, and (2) reduced multiplexer effects on high-impedance measurements.

NOTE

With the multiplexer disabled, internal calibration and zero are affected by changes in input level, particularly on ohms and the 300V range. Whenever the applied input signal changes, press the selected function button to perform an auto zero/cal routine; otherwise, substantial measurement errors will result. Zero and calibration may also drift with time; thus, it is recommended that the selected function button be pressed periodically to attain optimum accuracy while auto cal/zero is disabled (multiplexer off). An auto zero/cal is performed whenever the range or function is changed.

Run this program as follows:

1. Press DMM SETUP and then NEXT as required until the following message is displayed:

   MUX ON

2. Use uprange or downrange to select multiplexer on/off, as required. For multiplexer off, the instrument will display:

   MUX OFF

3. Once the desired multiplexer status is displayed, press NEXT to scroll to the next program and save current multiplexer status.

2.7.3 IEEE-488 Primary Address Programming

The IEEE-488 primary address program allows you check or modify the IEEE-488 primary address of the instrument. The factory default primary address is 26, but it can be programmed to any valid value between 0 and 30 as outlined below. Section 3 contains detailed information on IEEE-488 programming.

Perform the following steps to use this program.

1. Press SHIFT DMM SETUP and then NEXT repeatedly until the following message is displayed:

   26 IEEE

Here we have assumed the factory default primary address of 26.

2. To exit the program without changing the address, press NEXT.
3. To change the address, key in the desired digits in the range of 0-30, and press NEXT to go on to the following program.

NOTES:

1. If an invalid address is entered, the primary address will be set to 30 upon exiting the program.
2. To change the default address of the instrument, first set the address to the desired value, and then use the save setup program (or send L1 over the bus). Cycling power, or sending SDC, DCL, or L0 over the bus will not affect the newly-saved default primary address.
3. If the IEEE-488 primary address is changed but not saved, cycling power will return the instrument to the original default address. However, program reset, or DCL or SDC commands will not affect the current address. Sending L0 over the bus will not change the current address, but it will change the default address to the new value.
4. An "UNCAL" error will default the address to 26 and the line frequency setting to 60Hz.

2.7.4 Line Frequency

The programmed line frequency should match that of the power line voltage in order for the instrument to meet its noise specifications at 5½-digit resolution (line cycle integration is used at 5½-digit resolution). The line frequency program can be used to check the programmed line frequency and set it to 50 or 60Hz.

Proceed as follows in order to check or set the line frequency:

1. Press SHIFT DMM SETUP and then NEXT repeatedly until the line frequency message is displayed. For 60Hz, the display will show:

   FREQ=60Hz

2. For 50Hz, the display message is:

   FREQ=50Hz

3. Use uprange or downrange to toggle to the desired frequency, then press NEXT to go on to the next program.

NOTES:

1. To change the default frequency setting, first select the desired frequency and then use the save setup program (or send L1 over the bus) to save the new frequency setting. Cycling power, or sending SDC, DCL, or L0 over the bus will not affect the programmed line frequency.
2. If the line frequency is changed but not saved with the save setup program, sending SDC or DCL over the bus will return the line frequency to the default setting. However, the reset program will not have any effect on the current frequency setting, and sending L0 over the bus will not change the setting, but will save the new frequency.
3. An "UNCAL" error will default the IEEE-488 primary address to 26 and set the line frequency to 60Hz.

2.7.5 Save Setup

The save setup program allows you to save current instrument conditions. These conditions will then be assumed upon power up, or after the instrument receives the DCL or SDC command over the IEEE-488 bus.

The following operating parameters are saved by this program:

Function
Range
Resolution
Zero state (on/off)
Filter state (on/off)
AC dB state (on/off)
Multiplexer (on/off)
Trigger delay
Reading interval
IEEE-488 primary address
Line frequency (50 or 60Hz)

In order to save an instrument setup, proceed as follows:

1. Setup instrument operating conditions as desired, or use the reset program (paragraph 2.7.8) to save default operating conditions.
2. Press SHIFT DMM SETUP and then NEXT until the following message appears:

   SAVE NO

3. Use uprange or downrange to toggle to the following message:

   SAVE YES

4. To save instrument setup conditions, press NEXT. The unit will save the operating states and then go on to the next program.

NOTES:

1. To exit the program without changing the previous default conditions, press NEXT with the "SAVE NO" message displayed.
2. To return the instrument to the factory power up default conditions, use the reset program and then save those conditions using the save setup program.

2.7.6 LED Test

This program allows you to test all the front panel annunciators and LED display segments to check for proper operation. Proceed as follows:

1. Press DMM SETUP and then NEXT repeatedly until the following message is displayed:

   LEDS OFF

2. To test the LEDs, use uprange or downrange to toggle the display to the following:

   LEDS ON

3. Press NEXT to initiate the test.
4. During the test, the instrument will turn on all the annunciators and walk through the various display segments and complete displays to verify that all are operating properly. Following the test, the instrument will scroll to the next program.

2.7.7 Debug

The debug program is intended to switch various LEDs, relays, and logic levels to allow signal tracing through the instrument during troubleshooting. Also, memory tests are performed. For complete details on using the debug, refer to paragraph 6.7.3.

To exit the diagnostic program, press any key except TRIGGER.

2.7.8 Reset

The reset program restores instrument setup parameters to the factory default conditions listed in Tables 2-1 and 3-7.

Perform the following steps to use this program.

1. Press SHIFT DMM SETUP and then NEXT repeatedly until the following message is displayed:

   RESET NO

2. Use uprange or downrange to toggle the display as follows:

   RESET YES

3. Press NEXT to reset the instrument, which will return to the default conditions listed in Table 2-1.

NOTES:

1. The reset program can be aborted by pressing NEXT with the "RESET NO" message displayed.
2. Once the instrument has been reset to default conditions, use save setup to save that configuration if you desire that the instrument power up in those conditions.
3. The reset program has no effect on the programmed IEEE-488 primary address or line frequency setting.

2.8 FRONT PANEL TRIGGERING

The following paragraphs discuss front panel triggering, trigger mode selection, as well as trigger delay and reading interval programming.

2.8.1 Trigger Mode Selection

The Model 199 may be operated in two basic trigger modes: one-shot and continuous. In the one-shot mode, a separate trigger is required to initiate each reading. For the continuous mode, however, only a single trigger is required, with the conversion rate determined by the programmed reading interval. The continuous trigger mode is the factory default.

To check or change the selected trigger mode, proceed as follows.

1. Press SHIFT TRIG SETUP. The instrument will display the presently selected trigger mode. For the continuous mode, the display will show:

   CONTINUOUS

2. For the one-shot mode, the display reads:

   ONE SHOT

3. To toggle the trigger mode, press uprange or downrange.
4. Once the desired trigger mode is displayed, press NEXT to scroll to the next menu selection (trigger delay), or press NEXT to return to normal front panel display.

2.8.2 Trigger Sources

For standard bench operation, there are two trigger sources available: front panel TRIGGER button, and the EXTERNAL TRIGGER INPUT jack. Upon power up both these trigger sources will be enabled. Additional triggers include IEEE-488 X, GET, and talk commands, as discussed in paragraph 3.9.7.

NOTES:

1. TRIGGER is always enabled regardless of the selected trigger source; however, all front panel buttons will be locked out when the unit is in remote.
2. Triggering the unit while it is still processing a reading from a previous trigger will generate the "TRIGGER OVERRUN" message.

2.8.3 Trigger Delay

The trigger delay period is the time from the trigger point until the unit takes a reading. This delay period is also used after each channel closure when using the scanner. For the continuous mode, the delay period affects only the first conversion; however, with the one-shot mode, the delay period affects every conversion, with the instrument waiting the programmed delay time after each trigger before taking a reading. For example, if you program a 300msec trigger delay, the unit will wait 300msec after each trigger before taking a reading.

The allowable range for the trigger delay period is between 0 and 999.999 seconds in one millisecond increments. The trigger delay can be programmed with the TRIG SETUP key, as described below.

1. Press SHIFT TRIG SETUP and then NEXT and note the following message is displayed briefly:

   DELAY=
   000.000S

   Here, we have assumed the factory default delay period of 0sec.
2. Using the the data entry keys (0-9), key in the desired trigger delay period in the range of 0-999.999sec.
3. Once the desired delay value is programmed, press NEXT to go on to the interval selection (or press NEXT once more to return to normal display).

2.8.4 Reading Interval

The reading interval parameter determines the time period between individual readings when the instrument is in the continuous trigger mode. Interval also affects the rate of data store operation, as discussed in paragraph 2.10, as well as the interval between channels (step mode) or scan sequences (scan mode) when using the optional Model 1992 Scanner (see paragraph 2.11).

The unit can be programmed for either default or selected interval operation. With default interval ("SELECT OFF"), a preset interval of 175msec is automatically selected. With selected interval ("SELECT ON") a user-defined interval can be programmed. The allowable range for selected interval is 15msec to 999.999sec in 1msec increments.

NOTE

Programming too short an interval for the present instrument configuration when using the scanner or data store will result in the "INTERVAL OVERRUN" message. The interval cannot be programmed if the unit is in the one-shot trigger mode.

Reading interval can be checked or programmed with the TRIG SETUP key, as follows.

1. Press SHIFT TRIG SETUP and then NEXT repeatedly until the following is displayed:

   INTERVAL

   Next, the unit displays:

   SELECT OFF

   or,

   SELECT ON

2. Use uprange or downrange to select the desired interval type, select or default, then press NEXT. If default (SELECT OFF) is selected, the interval will be set to 175msec, and the unit will return to normal display.
3. If select interval is chosen, the presently selected interval will then be displayed, as in this example:

   INTERVAL =
   000.175 S

   Here we have assumed the default interval of 175msec.
4. If desired, key in a new reading interval in the range of 15msec to 999.999sec.
5. Once the desired interval is displayed, press NEXT to return to normal display. If you progam too small an interval, the following will be displayed:

   MIN = .015 S

2.8.5 Trigger Programming Examples

Example 1: Continuous with 3.5sec intervals between readings.

1. Press SHIFT TRIG SETUP and then uprange or downrange (if necessary) so the unit displays the following:

   CONTINUOUS

2. Press NEXT twice to advance to the interval display message.
3. Use uprange or downrange to choose select interval ("SELECT ON"), if necessary, then press NEXT.
4. Press: 0 0 3 5 0 0 in order to program a 3.5sec interval.
5. Press NEXT to return to normal display.
6. Connect a time-varying signal to the instrument, and select a function and range suitable for the applied signal.
7. Press TRIGGER to initiate readings. Note that the display updates at a rate of once every 3½ seconds, as shown by the following decimal point.

Example 2: One-shot trigger mode with a one second trigger delay.

1. Press SHIFT TRIG SETUP and then uprange or downrange (if necessary) so the unit displays the following:

   ONE SHOT

2. Press NEXT to advance to the delay time selection.
3. Press: 0 0 1 0 0 0 to program a one second delay.
4. Press NEXT to return to normal display.
5. Connect a time-varying signal, and select an appropriate range and function.
6. Press TRIGGER to initiate a single reading. Note that the display updates once after a delay of approximately one second.
7. Press TRIGGER a number of times, and note that one reading per trigger is processed with a one second interval between triggers and readings. The trigger status LED (flashing decimal point) indicates the display update.

2.9 EXTERNAL TRIGGERING

The Model 199 has two external BNC connectors on the rear panel associated with instrument triggering. The EXTERNAL TRIGGER INPUT connector allows the instrument to be triggered by other devices, while the METER COMPLETE OUTPUT connector allows the instrument to trigger other devices.

2.9.1 External Trigger

The external trigger input requires a falling edge pulse at TTL logic levels, as shown in Figure 2-8. Connections to the rear panel EXTERNAL TRIGGER INPUT jack should be made with a standard BNC connector. If the instrument is in the external trigger mode, it will be triggered to take readings while in either a continuous or one-shot mode when the negative-going edge of the external trigger pulse occurs.

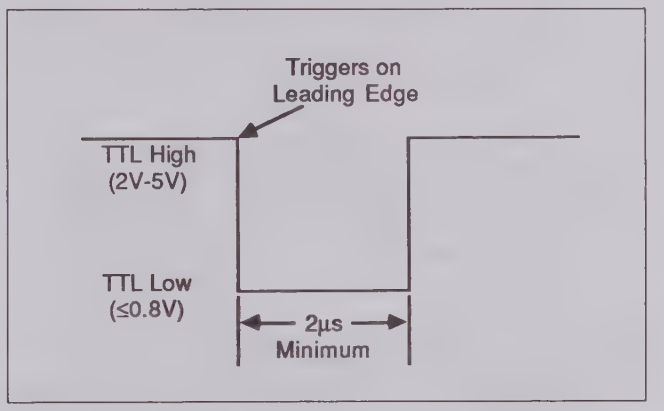


Figure 2-8. External Trigger Pulse Specifications

To use the external trigger, proceed as follows:

1. Connect the external trigger source to the rear panel BNC EXTERNAL TRIGGER INPUT connector. The shield (outer) part of the connector is connected to digital common. Since an internal pull-up resistor is used, a mechanical switch may be connected across the jack contacts. Note however, that debouncing circuitry will probably be required to avoid a trigger overrun.

WARNING
Do not exceed 30V between digital common and chassis ground, to avoid a shock hazard and possible instrument damage.

2. Place the instrument in "one-shot on external trigger" or "continuous on external trigger" mode as explained in paragraph 2.8.1.
3. To trigger the instrument, apply a pulse to the external trigger input. The instrument will process a single reading each time the pulse is applied (one-shot), or start a continuous series of readings.

NOTE

Triggering the unit while it is processing a reading from a previous trigger will cause a "TRIGGER OVERRUN".

2.9.2 Meter Complete

The Model 199 has an available output pulse that can be used to trigger other instrumentation. A single TTL-compatible negative-going pulse (see Figure 2-9) will appear at the METER COMPLETE OUTPUT jack each time the instrument completes a reading. To use the voltmeter complete output, proceed as follows:

1. Connect the Model 199 to the instrument to be triggered with a suitable shielded cable. Use a standard BNC connector to make the connection to the Model 199.

WARNING

Do not exceed 30V between the METER COMPLETE common (outer ring) and chassis ground to avoid a shock hazard and possible instrument damage.

2. Select the desired function, range, trigger mode, and other operating parameters, as desired.
3. In a continuous trigger mode, the instrument will output pulses at the conversion rate; each pulse will occur after the Model 199 has completed a conversion.
4. In a one-shot trigger mode, the Model 199 will output a pulse once each time it completes a reading after being triggered.

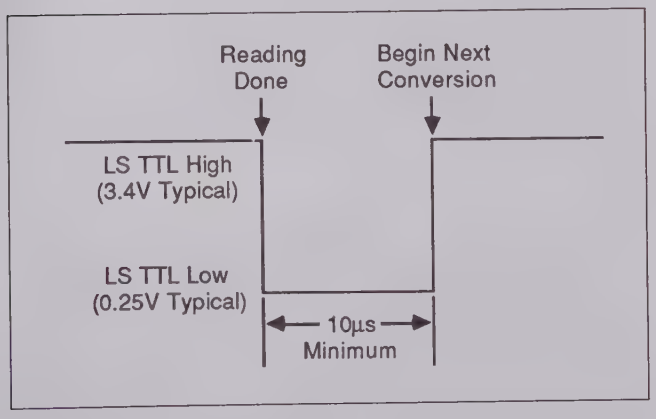


Figure 2-9. Meter Complete Pulse Specifications

2.10 DATA STORE

Data Store can store up to 500 readings for later recall. Data can be stored at specified intervals of between 15msec and 999.999sec with 1msec increments. In addition, one-shot external or front panel triggering can be used to store data at user-defined rates.

The following paragraphs describe front panel operating procedures for storing and recalling data.

2.10.1 Storing Data at Programmed Intervals

Use the following procedure for storing data at defined intervals.

1. Select the function and range to be used to make measurements.
2. Press SHIFT TRIG SETUP and verify that the continuous trigger mode is selected as follows:

CONTINUOUS

3. If necessary, press uprange or downrange to select the continuous trigger mode, then press NEXT and set the trigger delay to the desired value.
4. Press NEXT, then use uprange or downrange to choose "SELECT OFF" (175msec) or "SELECT ON" (user-programmed) data store interval, then press NEXT.
5. For select interval only, enter the desired data storage interval in the range of 15msec to 999.999sec. For example, to enter a one-second interval, press: 0 0 1 0 0 0, then press NEXT to complete interval programming.
6. Press SHIFT STORE to enter data store mode. The instrument will display the programmed data store size:

000 SIZE

The size value determines how many readings will be stored (up to a maximum of 500) before the storage cycle stops. However, a size of 000 indicates that the storage cycle will continue even after all 500 readings are stored. After, the 500th reading is stored, readings will be stored beginning at the first memory location, overwriting the previously stored data.

7. Key in the desired number of readings (use 000 for wrap around storage), then press the NEXT key to program that value. STO will flash on to indicate the unit is waiting for a trigger.

8. Press TRIGGER to initiate storage. The instrument will begin storing data at the programmed interval. While storage is active, you can display the most recently stored location by entering the recall mode (see paragraph 2.10.3).
9. After all readings have been stored, the RCL indicator will start flashing, and STO will turn off to indicate that the storage process has been completed (except for continuous storage).

NOTES:

1. Once data storage is initiated, data store can be disabled by pressing any function key (VOLTS, OHMS, etc). Doing so will select that function. However, if recall is also enabled, first press NEXT then the desired function key to disable data store.
2. Autoranging can be used with data store, but it must be selected before entering data store.
3. The front panel "INTERVAL OVERRUN" message indicates that the programmed data store interval is too short for the present instrument configuration. Although the instrument will continue to store readings as fast as it can, storage will not occur at the programmed interval under these conditions.
4. Enabling data store clears the buffer of previously stored readings.
5. If a data store size larger than 500 readings is programmed, the following message will be displayed:

MAX = 500

2.10.2 Triggering One-shot Readings into Data Store

Reading storage can be controlled by trigger pulses applied to rear panel EXTERNAL TRIGGER INPUT (paragraph 2.9), or by using the front panel TRIGGER button, as described below. The procedure below assumes that the default trigger source has not been altered by programming the instrument over the IEEE-488 bus.

1. Select the function and range to be used to make the measurements (autorange can be used with data store).
2. Press SHIFT TRIG SETUP, and then select the one-shot trigger mode by pressing uprange or downrange so the following is displayed:

ONE SHOT

3. Press NEXT and program the desired trigger delay. Press NEXT, note that dashes remain in the display because the instrument has yet to be triggered.
4. Press SHIFT STORE to enter the data store; the unit will display the programmed size:

000 SIZE

5. Key in the desired number of readings to store (1-500), or select a size of 000 for wrap around storage. Press NEXT to complete programming. The STO light will then flash to indicate the instrument is waiting for a trigger.
6. Press the TRIGGER button to trigger the unit, or apply a trigger pulse to the unit (see paragraph 2.9.1). A single reading will be processed and stored with each trigger stimulus.

NOTES:

1. Data can be recalled during the storage process, as described in paragraph 2.10.3.
2. To disable data store and return to normal operation, press any function key. If recall is also enabled, you must first press NEXT to cancel recall and then press any function key.
3. The RCL indicator will flash on when all programmed readings have been stored (except in continuous).
4. A "TRIGGER OVERRUN" error will occur if the unit is triggered while processing a reading from a previous trigger. The current reading will not be aborted and the error triggers will be buffered to re-trigger the unit when it is ready.

2.10.3 Recalling Data

Data can be recalled either during storage or after storage is complete by using the procedure below.

1. Press SHIFT RECALL to display data. The instrument will turn on the RCL indicator and display the location of the last stored data point; for example, for location 35:

035 LOC

2. For sequential access, use the uprange or downrange key while displaying the data value. Uprange increments locations, while downrange decrements locations. The location will wrap around to the opposite end of the data store buffer once the lowest or highest location is accessed.
3. To display a particular data location number while in the recall mode, press the RECALL key. Press NEXT to return to normal recall data display.
4. For random access to a particular location, key in the location number with the data entry keys, and then

press the NEXT key. The unit will then display the data value at that location along with the measurement function in effect at the time the data was taken.

5. To exit the recall mode, press NEXT while normal recall data is displayed. RCL will turn off to indicate that recall has been disabled.

NOTES:

1. If data store has no valid data to display, the unit will display the following message upon entry to the recall mode.

NO DATA

2. The unit will continue to store data while in recall until the data store buffer is full (or continuously in wrap around mode).

2.11 SCANNER OPERATION (WITH OPTION 1992)

With the optional Model 1992 Scanner installed, the Model 199 can scan four, 4-pole channels, or eight, 2-pole channels. The following paragraphs discuss scanner programming, connections, and operation from the front panel. Refer to paragraph 3.12 for IEEE-488 scanner programming. For scanner installation procedures, refer to Section 6.

2.11.1 Scanner Connections

Figure 2-10 shows the Model 1992 Scanner Card and its two quick-disconnect terminal blocks. To remove each block from the card, simply pull on the attached handle until it comes free of the card. Screw terminals on the blocks accept up to #14AWG solid or stranded wire.

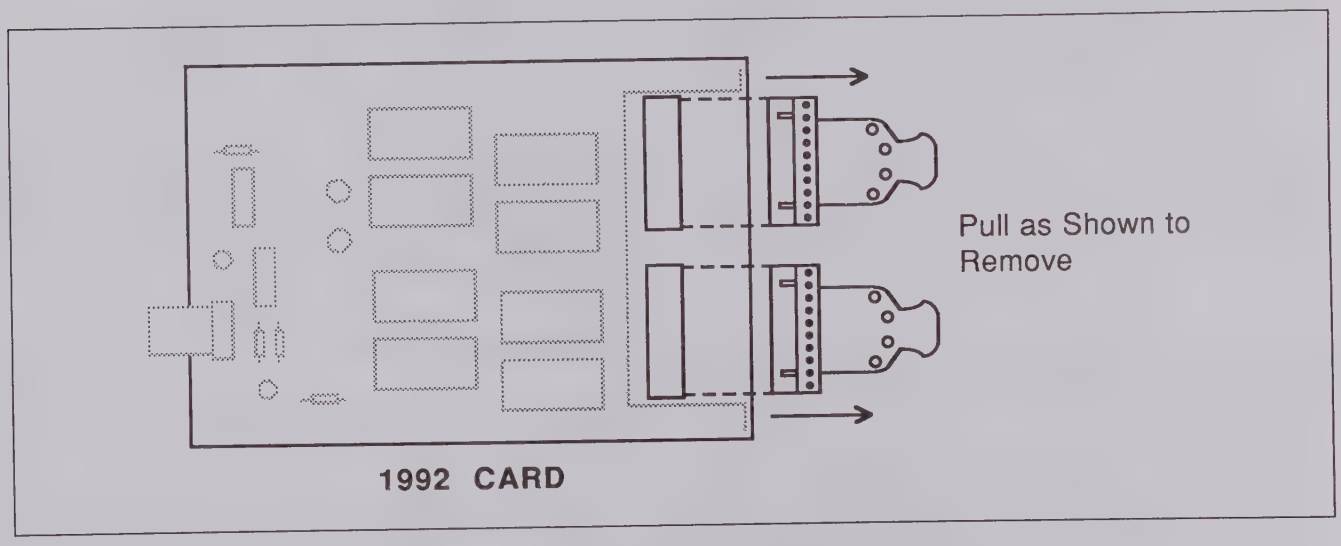


Figure 2-10. Scanner Connections

Terminal configurations are marked on the circuit board and connecting blocks. Channel input terminals are marked CH1 through CH8 inclusive. Each channel input has a HI and LO terminal, labelled H and L respectively. Two sets of output terminals, OUT A and OUT B, are also located on the connecting blocks. The output configuration depends on the whether 2-pole or 4-pole mode is to be used, as discussed below.

WARNING

Maximum common mode voltage (potential between any contact and earth ground) is 350V peak. Exceeding this value may create a shock hazard.

WARNING

User-supplied lethal voltages may be present on the scanner card terminals.

CAUTION

Maximum scanner signal level is 200V, 100μA; any terminal to earth ground is 350V peak. Exceeding these values may damage the scanner card.

Using the Supplied Output Cables

Red and black output cables with banana plugs are supplied with the scanner for convenient connections to the rear panel input jacks. Prepare and connect these cables as follows:

1. Strip the ends of the cables ≈5/16", then twist the strands together.
2. Connect the red cables to OUT A HI and OUT B HI. Tighten screws securely.
3. Connect the black cables to OUT A LO and OUT B LO. Tighten screws securely.
4. For 2-pole connections, plug the two red cables and two black cables together, and then plug them into the rear panel VOLTS OHMS HI (red) and LO (black) jacks (Figure 2-11A).
5. For 4-pole connections, plug the cables in as shown in Figure 2-11B.

2-pole Connections

Two-pole connections are used for volts and 2-wire resistance measurements. In order to use the 2-pole mode, the OUT A and OUT B terminals must be connected together (H to H, L to L) and to the DMM. In the 2-pole mode, if only OUT A is connected to the DMM input, only channels 1-4 will be routed through the relays. Similarly, channels 5-8 will be available if only OUT B is connected.

For volts and 2-wire resistance measurements, connect the outputs to the VOLTS OHMS terminals (H to HI, L to LO). The rear panel input jacks are most convenient for this configuration.

NOTE

Make sure the INPUT switch is set for the rear input terminals.

Figure 2-12 shows typical input connections for voltage measurements. Input connections for 2-wire ohms measurements are shown in Figure and 2-13.

4-pole Connections

Four-pole connections are used exclusively for 4-wire ohms measurements. With this configuration, the paired channels (1 and 5, 2 and 6, 3 and 7, 4 and 8) must be connected to the resistances under test, as shown in the typical connections of Figure 2-14. The two outputs are separately connected to VOLTS OHMS and OHMS SENSE terminals using the supplied output cables. Note that the two outputs must not be connected together in the 4-pole mode.

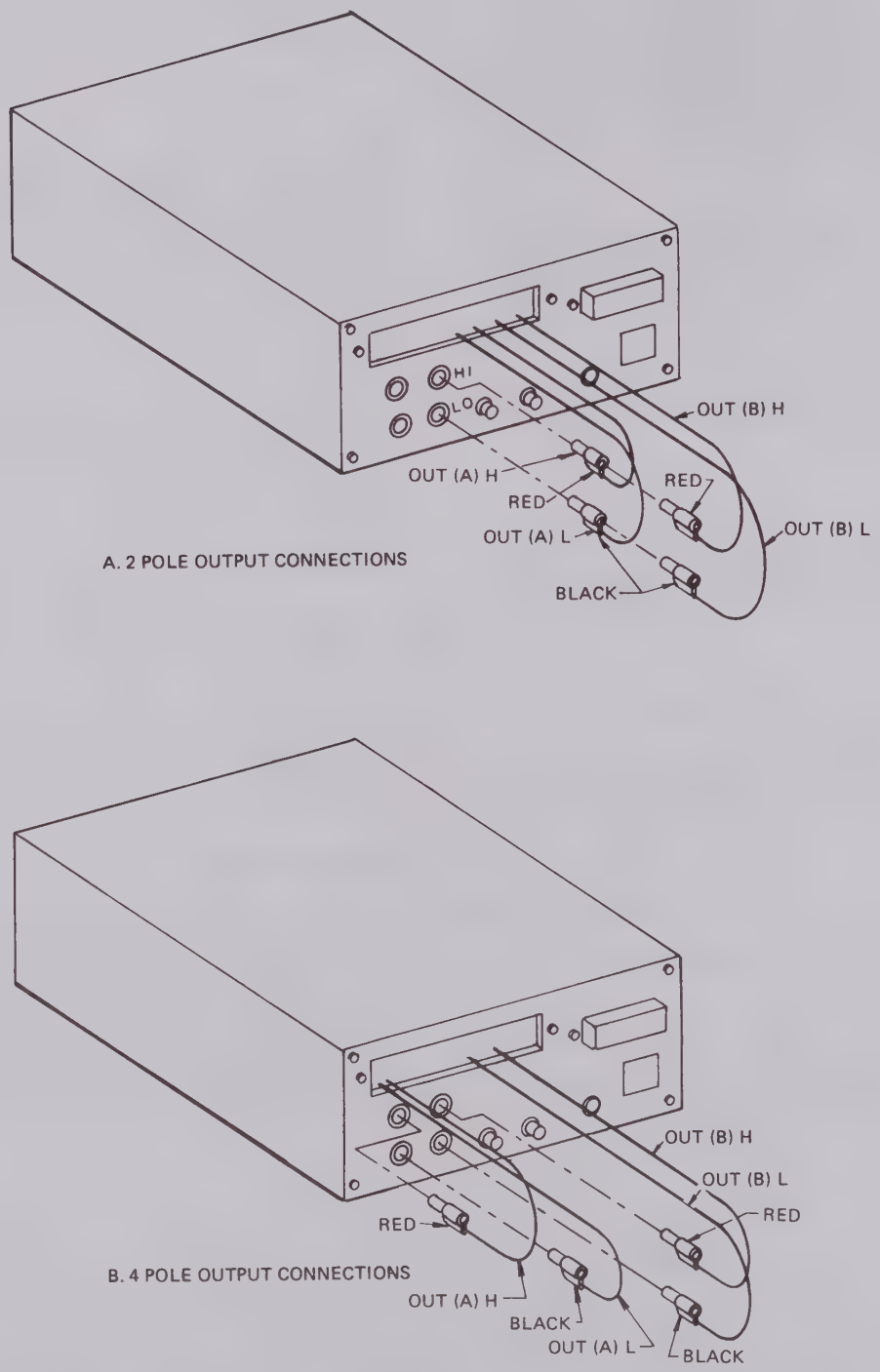


Figure 2-11. Output Cable Connections

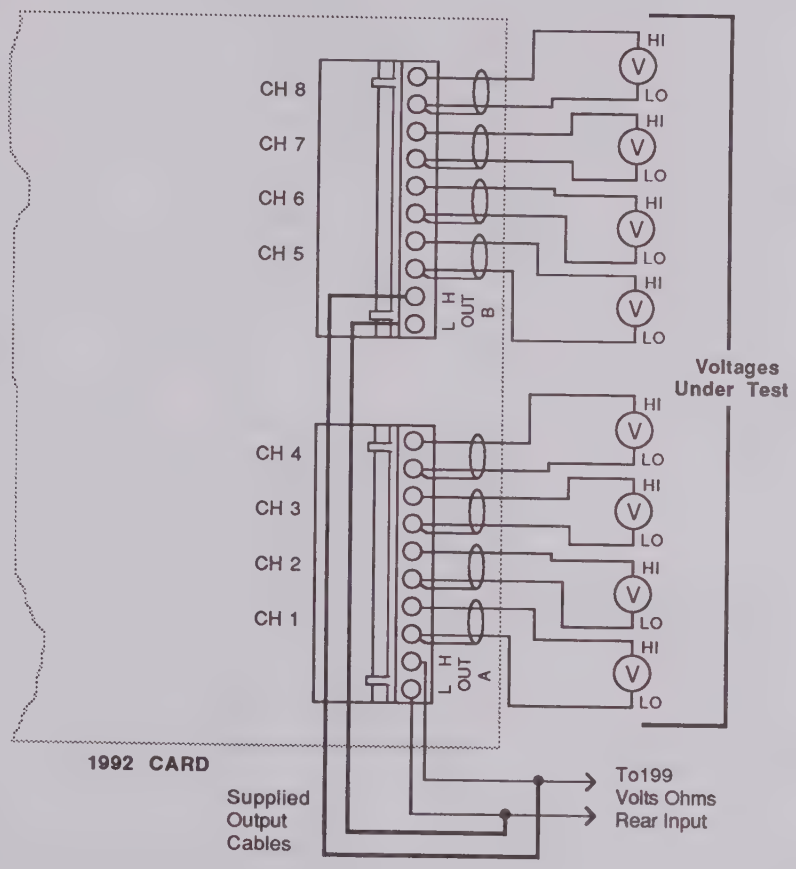


Figure 2-12. Voltage Test Connections

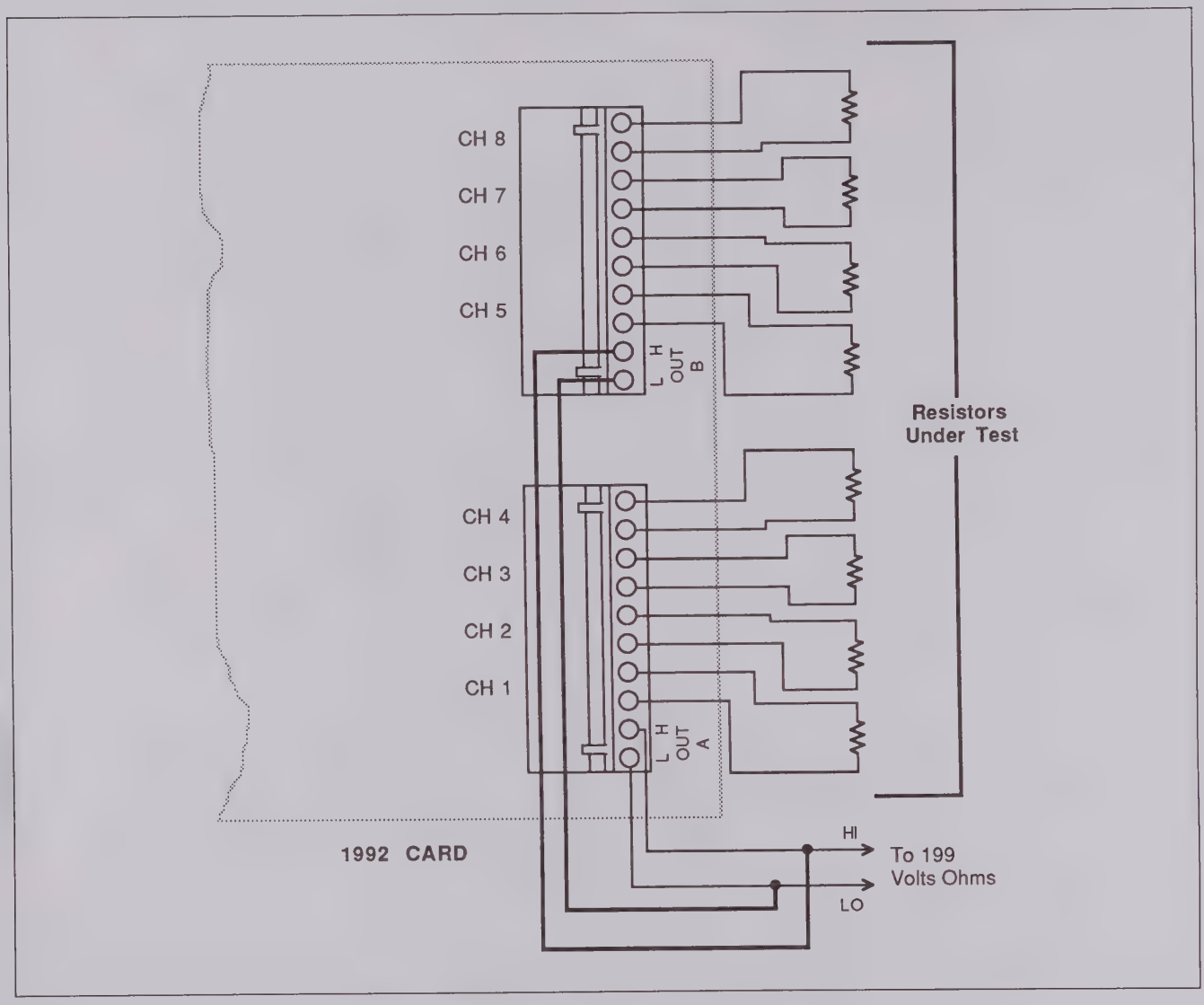


Figure 2-13. 2-Pole Resistor Test Connections

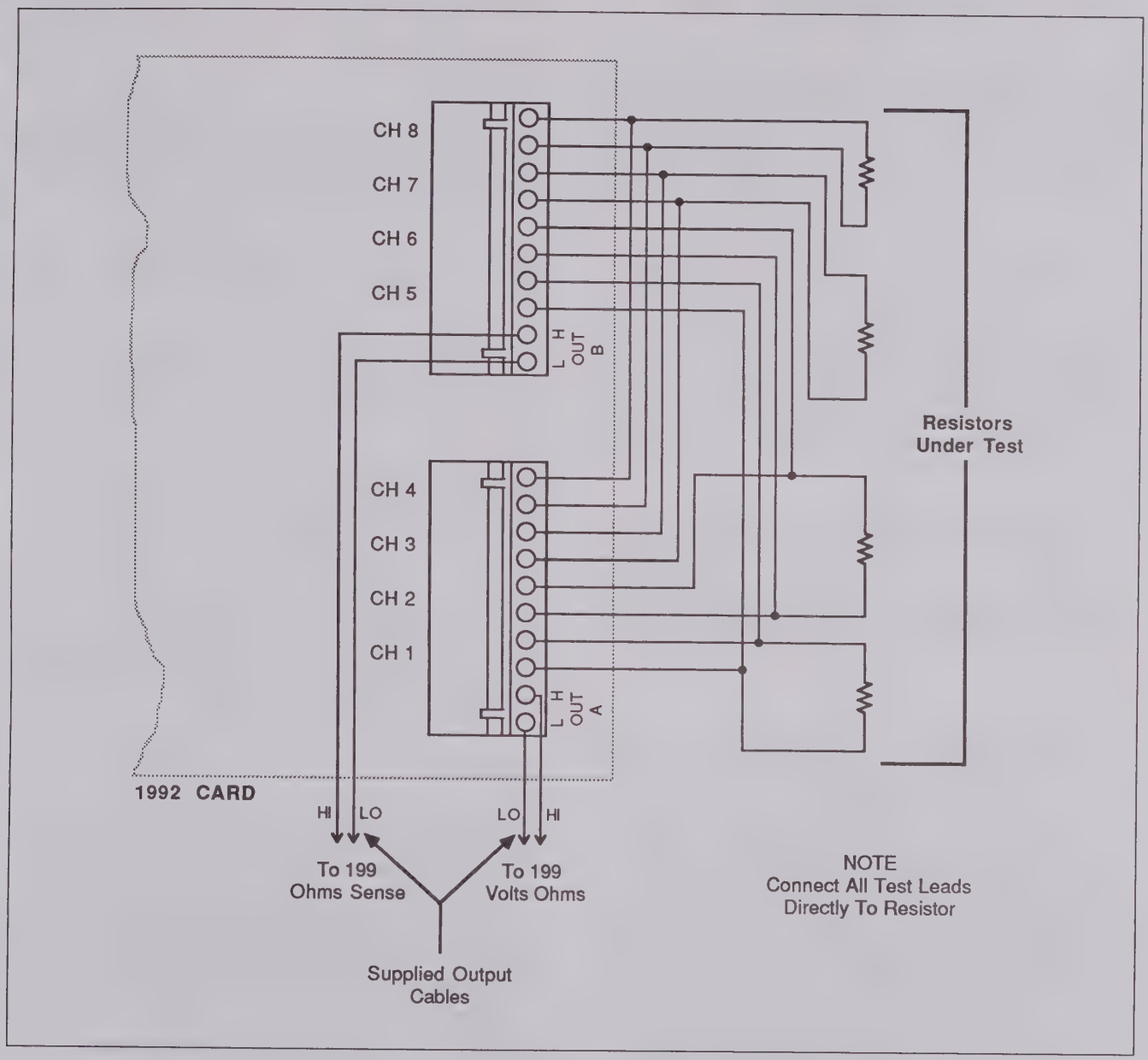


Figure 2-14. 4-Pole Resistor Test Connections

2.11.2 Scanner Display Format

The front panel display format is similar to normal display format with one important exception: The channel number appears in the right most digit of the display while the scanner is operating. The selected measuring function will also appear on the display except when on channels 2 through 8 while in the ratio mode. The ratio mode is discussed in detail in paragraph 2.11.5.

2.11.3 Pole Mode Programming

As discussed in paragraph 2.11.1, the 2-pole mode is intended for use with volts, and 2-wire ohms measurements, while the 4-pole mode is designed for use with 4-wire resistance measurements. For proper operation, the programmed pole mode must agree with the pole configuration discussed in paragraph 2.11.1.

The pole mode can be programmed by using the SCAN SETUP key as outlined below.

1. Press SHIFT SCAN SETUP to display the pole mode. For the 2-pole mode, the display will appear as follows:

   2 POLE

2. For the 4-pole mode, the display shows:

   4 POLE

3. Use uprange or downrange as necessary to toggle the pole mode to the desired status.
4. Once the desired pole mode is selected, press NEXT once to advance to the next menu selection (ratio), or press NEXT three times to return to normal display.

NOTE

A "CHAN 4 MAX" error will occur if you attempt to select the 4-pole mode with a channel limit greater than four.

2.11.4 Ratio Mode

The ratio mode divides the channel 2 through 8 readings by the channel 1 reading as follows:

$$R = \frac{CHn}{CH1}$$

Where: R = ratio
CHn = channel 2 through 8
CH1 = CH 1

The ratio mode is available for all three scan modes (discussed below). While in ratio, the instrument displays the selected function for channel 1, and the actual ratios without units for channels 2 through 8.

Ratio can be enabled or disabled by using the SCAN SETUP key as follows:

1. Press SHIFT SCAN SETUP and then NEXT twice to display the current ratio status. With ratio disabled, the display is:

   RATIO OFF

2. For ratio enabled, the display shows:

   RATIO ON

3. To change the ratio status, press uprange or downrange.
4. Once the desired ratio status is displayed, press NEXT once to advance to the next selection, or press NEXT twice to return to normal display.

NOTES:

1. In the MANUAL mode, you must manually access channel 1 first before attempting to display the ratio on channels 2 through 8.
2. The ratio is automatically scaled if the range is changed after the channel 1 reading is taken in order to maintain a constant ratio reference value across ranges. For example, if you take a 10V channel 1 reading on the 30V reading, the ratio reference will remain 10V on the 300V range.
3. Setting the range lower than the channel 1 ratio reference reading will cause an overflow.
4. The minimum ratio display value is equal to the display resolution. The maximum ratio is 9.99999. Exceeding this value will cause an overflow error.

2.11.5 Reading Interval

The reading interval parameter determines the time period between channels for the STEP mode, or the time between channel sets in the SCAN mode when the unit is in the continuous trigger mode. (In one shot, the trigger period

determines the interval). Use the procedure below to program the scan interval.

1. Press SHIFT TRIG SETUP and then NEXT as necessary so that the "SELECT" message is displayed, then use uprange or downrange to select the desired interval mode and press NEXT. Keep in mind that a 175msec interval is automatically selected in the "SELECT OFF".
2. For the select interval, key in the desired scan interval in the range of 25msec to 999.99sec.
3. Press NEXT to complete interval programming once the desired interval is keyed in.

NOTES:

1. The programmed interval also affects the display update rate as well as the data store interval while in the continuous trigger mode.
2. Programming an interval that is too short for the present instrument configuration will result in the "INTERVAL OVERRUN" error. Under these conditions, the instrument will continue to scan as fast as it can, but it will not scan at the programmed interval.
3. Although the minimum programmable interval is 15msec, the minimum usable interval with the scanner is 25msec.
4. Scanning rate is affected by selected resolution, delay, multiplexer (on/off), filter (on/off), function, and range.

2.11.6 Scan Limit

For the STEP and SCAN modes, the channel limit must be programmed as the last step in the scanner setup process. Note that the pole configuration affects the maximum number of channels that can be scanned, and thus the channel limit. For the 2-pole configuration, the maximum limit is eight, while the 4-pole mode is limited to four (for both modes, the minimum limit is one). If you attempt to program an improper channel limit, the unit will briefly display the following:

CHAN 4 MAX

or,

CHAN 8 MAX

More information on channel limit programming can be found in paragraphs 2.11.8 and 2.11.9.

2.11.7 Manual Channel Mode

In the MANUAL channel mode, individual channels can be accessed by pressing the SCANNER key followed by the number of the channel to close. The basic procedure is outlined below.

1. Select the function and range required for the measurement.
2. Using TRIG SETUP, program the trigger mode and delay as required.
3. Press SHIFT SCAN SETUP and program 2-pole or 4-pole operation as necessary.
4. Press NEXT and note the displayed scan mode. If necessary, use uprange or downrange to select the following:

MANUAL

5. Press NEXT and disable or enable the ratio mode as required.
6. Press NEXT to complete scanner setup programming.
7. To close a specific channel, press SCANNER. The unit will prompt you for the channel to close:

CHANNEL?

8. Press the desired numeric key to close that channel. For example to close channel 3, press 3.
9. The unit will close the selected channel and display the channel number in the right most digit.
10. If you have selected the one-shot trigger mode, press TRIGGER to trigger a reading.
11. To select a different channel, press SCANNER followed by the new channel number. The unit will open the presently selected channel and then close the new channel (break before make).
12. To open all channels and return to normal operation, select channel 0 (press SCANNER 0).

NOTES:

1. When using the ratio mode, you must first access channel 1 to obtain a ratio reference reading before accessing other channels.
2. In the 4-pole mode, the maximum channel number is channel 4. Selecting channels 5 through 8 will generate a "CHAN 4 MAX" error.

2.11.8 Step Mode Operation

In the STEP mode, the instrument will scan one channel per reading interval (continuous trigger mode) or one channel per trigger (one-shot trigger mode). The procedures for setting up and using the unit are covered below.

Reading Interval Scanning

1. Select the function and range for the expected measurement.
2. Press SHIFT TRIG SETUP and select the continuous trigger mode using uprange or downrange.
3. Press NEXT twice to display the programmed interval mode. Use uprange or downrange to select the desired interval operation, then press NEXT.
4. For the select interval, key in the desired scan interval in the range of 25msec and 999.999sec, and press NEXT to complete programming.
5. Press SHIFT SCAN SETUP and program the pole configuration by pressing uprange or downrange.
6. Press NEXT and then uprange or downrange until the step mode is selected, as indicated by the following message.

STEP

7. Press NEXT and then select the desired ratio mode by using uprange or downrange.
8. Press NEXT to complete scanner setup programming.
9. Press SCANNER. The unit will prompt you for the last channel in the scan sequence as follows:

LIMIT?

10. Press the number key corresponding to the last channel in the sequence (remember that the last channel is channel 4 for the 4-pole mode).
11. After the channel limit has been selected, the instrument will return to normal display and begin the scan sequence with channel 1. As each channel is scanned, the unit will take a reading on that channel and display the results along with the selected channel number. The sequence repeats until the last channel, as determined by the programmed limit, is scanned. After the last channel, the sequence starts over again with channel 1.
12. To stop scanning and return to normal display select a limit of 0 (press SCANNER 0).

NOTES:

1. If an interval too short for the present configuration is selected, the instrument will display the "INTERVAL OVERRUN" message. The instrument will continue to step through channels, but it will not be able to scan the channels at the programmed intervals. The filter status, resolution, and selected function affects the overall reading rate, and thus the minimum interval that can be used.
2. The "CHAN 4 MAX" message will be displayed if you attempt to program a channel limit greater than four in the 4-pole mode.

One-shot Triggering

Use the general procedure below to use one-shot triggering to scan channels in the step mode.

1. Select the function and range as required for the expected measurement.
2. Press SHIFT TRIG SETUP, and select the one-shot trigger mode.
3. If a circuit settling time for each channel is required, program a trigger delay under the TRIG SETUP menu.
4. Return to normal display by pressing NEXT as necessary.
5. Press SHIFT SCAN SETUP, and program the pole configuration.
6. Press NEXT, and select the step mode with uprange or downrange.
7. Press NEXT, and program the ratio mode as required.
8. Press NEXT to return to normal display.
9. Press SCANNER, and program the channel limit at the prompt. Keep in mind that the maximum channel limit is 4 in the 4-pole mode.
10. Press TRIGGER (or apply an external trigger pulse) to close channel 1 and take a reading on that channel. The reading and channel number will appear on the display.
11. Trigger the unit to advance to the next channel and take the subsequent reading. One trigger per channel will be required; after all channels up to the programmed limit have been scanned, the unit will begin again with channel 1.
12. Program a channel limit of 0 to cancel the scan mode and return to normal display. To do so, press SCANNER 0.

NOTES:

1. The unit will display a "TRIGGER OVERRUN" message if it is triggered while processing a reading from a previous trigger. The error trigger will be ignored.
2. The Model 199 will display the "CHAN 4 MAX" message if you attempt to program a channel limit greater than 4 in the 4-pole mode.
3. In the ratio mode, channel 1 data will be displayed as the selected function, while channels 2 through 8 will be displayed as the ratio.

2.11.9 Scan Mode Operation

In the SCAN mode, the unit will scan one set of channels per programmed reading interval (continuous trigger mode), or one set of channels per trigger (one-shot trigger mode). The number of channels per sequence is determined by the program channel limit. The following paragraphs outline the general procedures for using scan.

Reading Interval Operation

1. Select the range and function as required.
2. Press SHIFT TRIG SETUP, and select the continous trigger mode with uprange or downrange.
3. Press NEXT twice to advance to the interval display, then use uprange or downrange to select interval.
4. For select interval, use the data entry keys to program the desired interval in the range of 25msec to 999.999sec. Keep in mind that the interval is the time period between channel sets-- not individual channels as is the case with the STEP mode.
5. Press NEXT to return to normal display once the desired interval has been programmed.
6. Press SHIFT SCAN SETUP, and program the pole and mode as desired.
7. Advance to the scan mode display by pressing NEXT, then select the scan mode with the following display:

SCAN

8. Press NEXT to program the ratio and return to normal display.
9. Press SCANNER, and program the channel limit at the following prompt:

LIMIT?

10. Key in the desired limit (1-8, 2-pole; 1-4, 4-pole) with the data entry keys.
11. The unit will then begin scanning one set of channels per programmed interval, displaying the channels numbers as they are sequenced.
12. To stop scanning and return to normal display, program a channel limit of 0. To do so, press SCANNER 0.

NOTES:

1. Because of the relatively rapid scanning rate, it may be difficult to read data from the display while the unit is scanning. For that reason, it is recommended that the SCAN mode be used with data store, as discussed in paragraph 2.11.11.
2. The "INTERVAL OVERRUN" message will be displayed if the unit cannot scan channel sets at the programmed interval.
3. The filter status, resolution, and function affects the overall reading rate, and thus the maximum scanning rate. For the fastest scan rate for a given function, turn off the filter, select 4½ digit resolution, and turn off the multiplexer.

Triggered Scanning

Each scan sequence can be triggered from the front panel or with an external trigger pulse by setting up the unit as follows.

1. Select the range and function as required.
2. Press SHIFT TRIG SETUP, and program the unit for the one-shot trigger mode.
3. Press NEXT, and program the desired trigger delay.
4. Press NEXT twice to return to normal display.
5. Press SHIFT SCAN SETUP, and program the pole mode as required.
6. Press NEXT to advance to the scan mode menu, then use uprange or downrange to select the SCAN mode.
7. Press NEXT to program the ratio and to return to normal display.
8. Press SCANNER, and program the channel limit as desired.
9. Press TRIGGER (or apply an external trigger pulse) to initiate the first scan SEQUENCE. The unit will scan all channels in the set and then stop. One trigger per SCAN SEQUENCE will be required.
10. To cancel the scan mode, program a channel limit of 0. To do so, press SCANNER 0.

NOTES:

1. Because of the rapid scan sequence in the scan mode, it is recommended that this mode be used with data store, as discussed in paragraph 2.11.11.
2. The unit will display the "TRIGGER OVERRUN" message if it is still processing a reading from a previous trigger.

2.11.10 Using Data Store with the Scanner

The data store feature of the Model 199 can be used with the scanner to store data for later recall. For short intervals in the STEP mode, and for the SCAN mode, using data store is the recommended method of operation because of the rapid scanning rates possible with the Model 199.

Scanning at Programmed Intervals

1. Select the range and function as required.
2. Press SHIFT TRIG SETUP, and program the continuous trigger mode.
3. Press NEXT twice to advance to the interval selection menu. Use uprange or downrange as necessary to select interval, then press NEXT.
4. With select interval, use the data entry keys to program the storage interval in the range of 25msec to 999.999sec. Keep in mind that the unit will store one channel per interval in the STEP mode, and one set of channels per interval in the SCAN mode.
5. Press NEXT to return to normal display after selecting the interval.
6. Press SHIFT SCAN SETUP, and program the pole mode as required.
7. Press NEXT to advance to the scan mode display. Use uprange or downrange to select the STEP (one channel per interval) or SCAN (one set of channels per interval) mode.
8. Press NEXT to program ratio and to return to normal display.
9. Press SCANNER, and program the desired channel limit. Scanning will begin at this point.
10. When the unit returns to normal display, press SHIFT STORE. Key in the desired number of readings to store. When storing data, the number of readings is equal to the number of channels per scan times the number of scan sequences desired. For example, if you desire to scan all eight channels with a total of 10 scan sequences, the data store size would be 80.
11. Press NEXT once the desired data store size has been selected. The STO indicator will flash on to show the unit is waiting for trigger. Scanning will also cease at this point.
12. Press TRIGGER (or apply an external trigger pulse) to initiate scanning at cahnnel 1 and storage. For the STEP mode, one channel per interval will be scanned and stored, while in the SCAN mode, one set of channels per trigger will be scanned and stored.
13. Press any function button to cancel data store. Scanning can be cancelled by programming a channel limit of 0.
14. Data can be recalled during or after storage as discussed below. RCL will flash when all locations are full (except in wrap-around mode).

One-Shot Trigger Data Store Scanning

Use the procedure below to trigger scanned data into data store. In the STEP mode, one channel per trigger will be scanned and stored, while in the SCAN mode, one set of channels per trigger will be scanned and stored.

1. Select the range and function as required.
2. Use TRIG SETUP to program the one-shot trigger mode.
3. Using SCAN SETUP, program the pole mode as required. Also select the STEP or SCAN modes under the SCAN SETUP menu. Return to normal display once all scanner setup programming has been completed.
4. Using the SCANNER button, program the desired channel limit.
5. Press SHIFT store, and then program the desired data store size in readings. The number of readings equals the number channels per scan sequence times the number of scan sequences. For example, if the channel limit is 4, the data store size would be 32 with eight scan sequences.
6. Press NEXT to exit the data store programming mode. The STO indicator will flash on to indicate the unit is waiting for a trigger.
7. Press TRIGGER to initiate the scan/storage sequence. One trigger per channel (STEP) or set of channels (SCAN) will be required to complete the sequence. When all readings have been taken, the RCL indicator will start flashing.
8. Program a limit of 0 to exit the scan sequence. The data can be recalled as outlined below.

Recalling Scanned Data

To recall scanner data from data store, simply press SHIFT RECALL to enter the recall mode. Press NEXT to view the last location, or key in the desired location number and then press the NEXT key to display the data, which will also include the channel number in addition to the function (except for ratio on channels 2 through 8 which displays ratio not function). Use uprange or downrange to scroll through locations, as required. You can exit the recall mode by pressing NEXT while scanned data is displayed.

Although the Model 199 does not display the scan sequence number, you can easily determine which sequence is being displayed by noting the data store location number (location number can be displayed by pressing RECALL while in the recall mode). For example, if eight channels were scanned, locations 1 through 8 would store channels 1 through 8 data for the first sequence, locations 9 through 16 would store channels 1 through 8 data from the second sequence, and so on.

2.11.11 A Practical Scanner Application: Amplifier Testing

The Model 199 equipped with the Model 1992 can perform tests on amplifiers with minimal external equipment. The following paragraphs discuss two such amplifier tests–gain and bandwidth testing.

Amplifier Gain

The ratio mode used in conjunction with the scanner can be used to determine the gain of seven different amplifier, using the test configuration shown in Figure 2-15. A signal generator is also necessary to supply the test signal to the inputs of the amplifiers, which are also connected to the channel 1 input of the scanner. Note that the outputs of the amplifiers are connected to the channels 2 through 8 inputs of the scanner. Because the maximum ratio the Model 199 can display is 10, amplifier gains are limited to that value. For higher gains, the values must be computed manually.

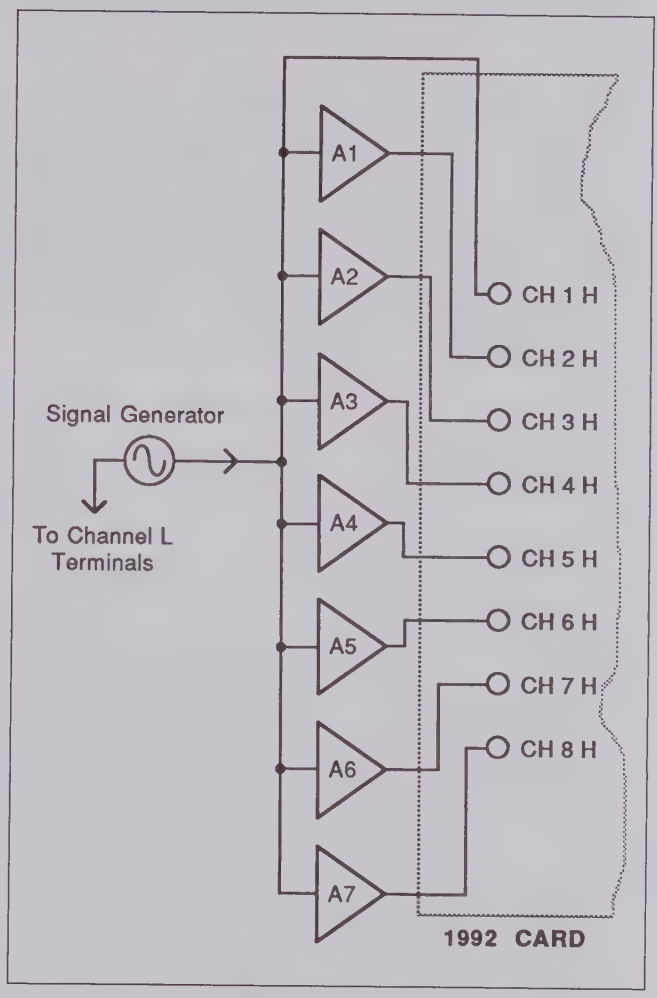


Figure 2-15. Amplifier Gain Test Configuration

In order to perform the gain tests, the following general procedure should be followed.

1. Connect the equipment together, as shown in Figure 2-15.
2. Assuming that AC gain is to be tested, place the Model 199 in the ACV function, and select a range high enough to measure the expected output voltages.
3. Press SHIFT TRIG SETUP, and select the one-shot trigger mode, then program a one-second delay. Return to normal display after programming the trigger mode and delay.
4. Press SHIFT SCAN SETUP, and program the 2-pole mode.
5. Press NEXT, and select the STEP scan mode with uprange or downrange.
6. Press NEXT, and turn on the ratio mode by using uprange or downrange.
7. Press NEXT to exit the scanner setup mode.
8. Press SCANNER, and select a channel limit of 8.
9. If you wish to store the amplifier gain data, press SHIFT STORE and select a reading size of 8. Press NEXT to return to normal display.
10. Set the signal generator to the desired output frequency (<300kHz) and amplitude for the gain test.
11. Press TRIGGER to initiate the scan. With the first trigger, the instrument will take amplifier input voltage reading on channel 1 and then store that reading as the ratio reference value.
12. Press TRIGGER to advance to channel 2. At this point, the instrument will display the ratio of channel 2 to channel 1, in other words, the gain of amplifier A1. To display the gains of the remaining amplifiers, press TRIGGER and note the displayed ratio for each channel.
13. If data store was enabled in step 9, press SHIFT RECALL to review the gain data. Select a location of 1, then press NEXT to view the data, which will be the absolute input voltage value. Press uprange to review channel 2 through 8 data, which will show the gain values of the respective amplifiers.

Amplifier Frequency Response

The test configuration discussed above can be modified somewhat to determine the bandwidth of eight amplifiers connected to the channel inputs. The equipment configuration for this test is shown in Figure 2-16. This test setup is similar to that shown in Figure 2-15.

To determine bandwidth, we can use the commonly-used -3dB points in frequency response. The dB function of the Model 199 simplifies this task a great deal.

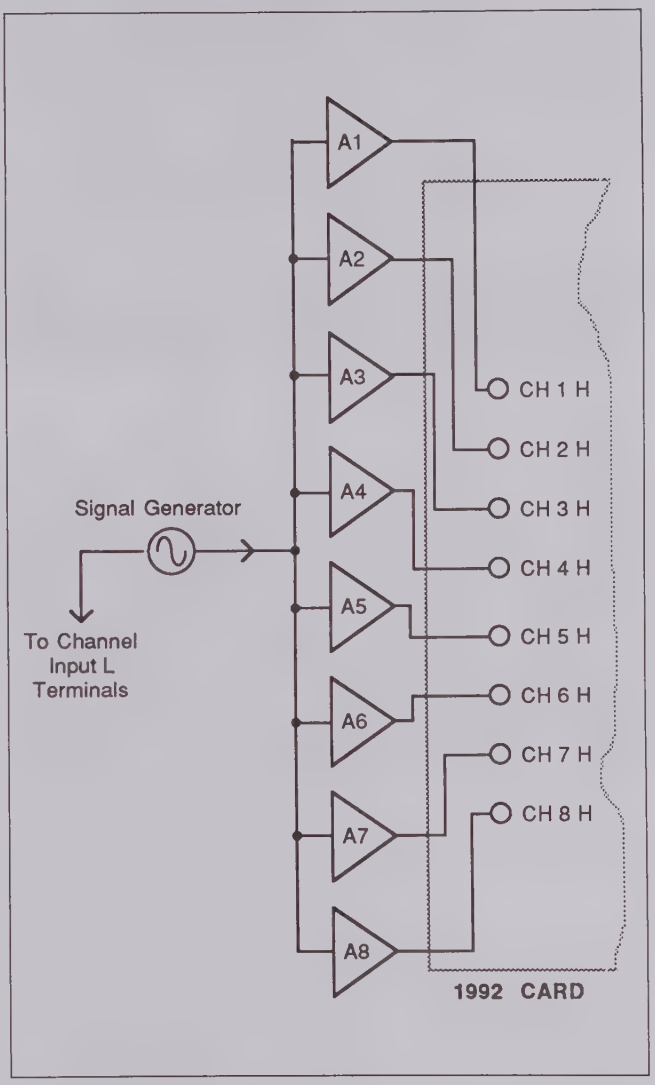


Figure 2-16. Amplifier Frequency Response Test Configuration

The basic test procedure is as follows.

1. Press SHIFT TRIG SETUP, and program the unit for the one-shot trigger mode.
2. Using SCAN SETUP, select the 2-pole, STEP scan, and ratio off modes.
3. Select the ACV function, then select a range large enough for the expected amplifier output voltages.
4. Program a channel limit of 8 with the SCANNER key.
5. Press SHIFT dB to select the dB function.
6. Set the signal generator to the desired amplitude and mid-band frequency (for example, 1kHz).
7. Press ZERO and then TRIGGER to store the 0dB reference value. The display should now show 0.00dB on channel 1.
8. Lower the generator frequency until the Model 199 displays −3.0dB. The present generator frequency is the lower half-power, or -3dB response point.
9. Raise the generator frequency above the mid-band point until the display again reads −3dB. The generator frequency now represents the upper half-power, or −3dB response point of the amplifier.
10. Press TRIGGER to advance the channel.
11. Repeat steps 7 through 10 for the remaining channels.

2.11.12 Low-level Measurement Considerations

The relay contacts of the Model 1992 Scanner Card have low-thermal characteristics (<1μV offset), allowing the card to be used for low-level measurements. The following paragraphs discuss methods to minimize the effects of potential error sources.

Thermoelectric Potentials

Thermoelectric potentials (thermal EMFs) are small electric potentials generated by differences in temperature at the junctions of dissimilar metals. Such thermoelectric potentials can seriously degrade low-level measurement accuracy. For example, a copper-to-copper oxide junction may generate up to 1000μV/°C, while a clean copper-to-copper junction will typically generate only 0.2μV/°C or less.

Ways to minimize the generation of thermoelectric potentials include:

1. Use only copper wires for all input and output connections. If lugs are used, they should be crimped on (not soldered), and they should also be made of copper.
2. Keep all connecting surfaces clean and free of oxides. Wires and lugs should be carefully cleaned before being mated together.
3. Keep connecting points and junctions at the same temperature.
4. Protect all circuits and connecting points from drafts.

Shielding

Shielding is important to keep noise out of low-level signal paths. To minimize problems in these areas, all input and output connections to the scanner card should be made using shielded cable when measuring low-level signals. The shields should be connected to signal LO (not earth ground) at the scanner card end for scanner input connections, and at the DMM end for scanner card output connections. Note that only one end of the shields should be connected to avoid possible ground loop problems; the other ends of the shields should be left floating.

2.11.13 Using the Scanner with Other Instrumentation

Although the scanner card is intended for use primarily with the Model 199 DMM, it can also be used with other instrumentation. For example, assume that the Model 1992 is to be used with a Keithley Model 181 Nanovoltmeter to make μV measurements requiring a higher input resistance than is available with the Model 199.

Typical connections for this arrangement are shown in Figure 2-17. Here, the scanner card outputs are connected to the Model 181 mV input using low-thermal cables. Likewise, all scanner inputs must be made with low-thermal cables. Use copper wire and keep all connections clean and free of oxidation. Also, all signal paths should be shielded as discussed above.

2.11.4 Scanner Delay

A channel settling time can be incorporated by programming the scanner delay with the TRIG SETUP key. When a scanner delay is used, the instrument will wait the programmed delay period after closing a channel before taking a reading. Thus, the delay period is essentially a channel settling time to allow signals to settle before each measurement.

The scanner delay (settling time) in the range of 0msec to 999.999sec can be programmed using TRIG SETUP as follows:

1. Press TRIG SETUP and then NEXT, and note that the instrument displays the following:

   DELAY=

   Followed by:

   000.000 S

2. Key in the desired delay period in the range of 0 to 999.99sec.
3. Press NEXT once to advance to the interval selection menu, or press NEXT twice to return to normal display.

NOTES:

1. A scanner delay of at least one second should be used when measuring AC signals. This recommendation is based on allowing the measurement to settle to within 0.1% of the final value.
2. The programmed interval must be longer than the delay to avoid the "INTERVAL OVERRUN" error.

2.11.5 Using Filtering with the Scanner

The Model 199 uses the running average type of filtering. When the front panel filter is on (FLTR on), additional averaging is used, as discussed in paragraph 2.6.3. For that reason, the reading rates are slower when the front panel filter is enabled.

For normal (non-scanner) operation, the display still updates while the filtering process is still going on. Under these conditions, the FLTR light blinks until the final, filtered reading is being displayed. With scanner operation, however, the unit will not advance to the next channel until the final, filtered reading has been taken. Thus, the maximum scan rates available will be slower with the filter on than with it turned off.

The instrument will advise you if you have exceeded the maximum scan rates. In the continuous trigger mode, the "INTERVAL OVERRUN" message will be displayed if the programmed interval is too short for the present instrument configuration. In teh one-shot trigger mode, the unit will display the "TRIGGER OVERRUN" message if it is still processing a reading when triggered.

2.11.16 Minimum Scan Interval Times

As discussed previously, the minimum usable interval depends on the function, range, resolution, as well as the multiplexer and filter states. Table 2-7 summarizes typical minimum interval times for various ranges and functions. Programming the instrument for shorter times will result in the "INTERVAL OVERRUN" message, in which case the unit will scan slower than the programmed interval.

Times for both the STEP and SCAN modes are given at both 4½ digit and 5½ digit resolution (where applicable), and all times are with internal filter on (FLTR off) and MUX ON. For DC and ohms functions, turning the internal filter off (using P0X over the bus) and mutiplexer off will shorten the times somewhat; times will typically be about 10-30% shorter with the multiplexer and filter off. Conversely, operating the instrument with the front panel filter on (FLTR on) will increase the minimum interval times.

Table 2-7. Typical Minimum Usable Scan Intervals

Range and Function	STEP Mode		SCAN Mode	
	4½ Digit	5½ Digit	4½ Digit	5½ Digit
30V DC	20msec	680msec	150msec	2.1sec
3V AC	20msec	35msec	150msec	270msec
300Ω	60msec	590msec	470msec	2sec
300kΩ	—	700msec	—	4.9sec
3MΩ	—	1.3sec	—	6.2sec
30MΩ	—	5.1sec	—	32sec
300MΩ	—	7sec	—	65sec
30mA DC	20msec	380msec	150msec	2.1sec
3A AC	20msec	35msec	150msec	270msec
ACV dB	46msec	—	360msec	—
ACA dB	37msec	—	360msec	—

NOTES:

1. All times are typical.
2. Times shown are with FLTR off, MUX ON.
3. Scan mode times are with eight-channel limit.

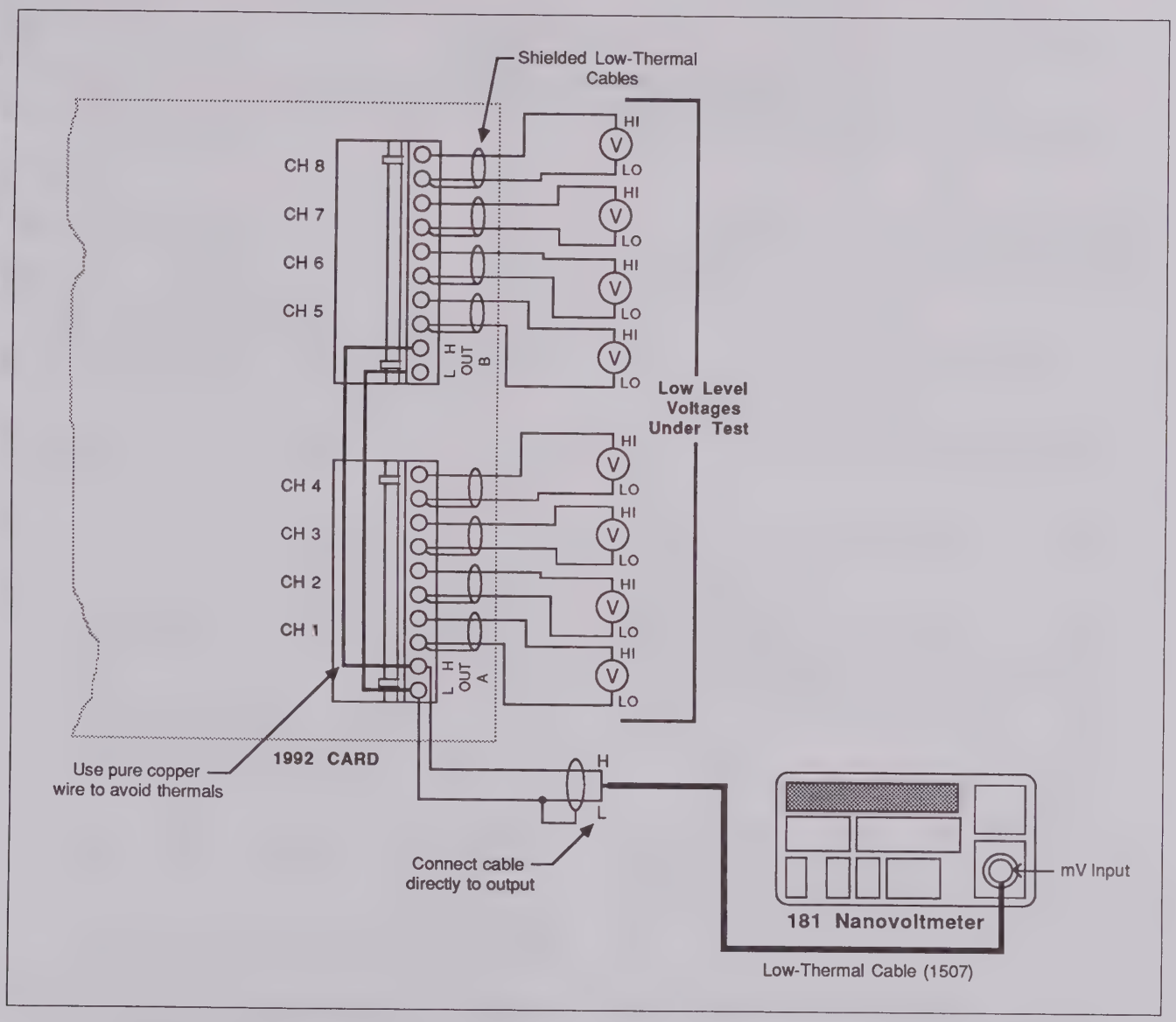


Figure 2-17. Using Scanner Card with Nanovoltmeter

SECTION 3
IEEE-488 Programming

3.1 INTRODUCTION

This section contains information on programming the Model 199 over the IEEE-488 bus. Detailed instructions for all programmable functions are included; however, information concerning operating modes presented elsewhere is not repeated here.

Additional IEEE-488 information is provided in the appendix.

Section 3 contains the following information:

3.2 **A Short-cut to IEEE-488 Operation:** Gives a simple step-by-step procedure for getting on the bus as quickly as possible.

3.3 **Bus Connections:** Shows typical methods for connecting the instrument to the bus.

3.4 **Interface Function Codes:** Defines IEEE standard codes that apply to the instrument.

3.5 **Primary Address Selection:** Tells how to program the instrument for the correct primary address.

3.6 **Controller Programming:** Demonstrates simple programming techniques for a typical IEEE-488 controller.

3.7 **Front Panel Aspects of IEEE-488 Operation:** Describes the operation of the bus status indicators, and summarizes front panel messages that may occur during bus operation.

3.8 **General Bus Command Programming:** Outlines methods for sending general bus commands to the instrument.

3.9 **Device-Dependent Commands:** Contains descriptions of most of the programming commands used to control the instrument over the bus.

3.10 **Using the Translator Mode:** Describes an alternate programming method of using easily recognized user-defined words in place of device-dependent commands.

3.11 **Bus Data Transmission Times:** Lists typical times when accessing instrument data over the bus.

3.12 **Scanner Programming:** Discusses programming commands used with the optional Model 1992 Scanner.

3.2 A SHORT-CUT TO IEEE-488 OPERATION

The paragraphs below will take you through a step-by-step procedure to get your Model 199 on the bus as quickly as possible and program basic operating modes. Refer to the remainder of Section 3 for detailed information on IEEE-488 operation and programming.

Step 1: Connect Your Model 199 to the Controller

With power off, connect the Model 199 to the IEEE-488 interface of the controller using a standard interface cable. Some controllers include an integral cable, while others require a separate cable. Paragraph 3.3 discusses bus connections in more detail.

Step 2: Select the Primary Address

Much like your home address, the primary address is a way for the controller to refer to each device on the bus individually. Consequently, the primary address of your Model 199 (and any other devices on the bus, for that matter), must be the same as the primary address specified in the controller's programming language, or you will not be able to program instrument operating modes and obtain data over the bus. Keep in mind that each device on the bus must have a different primary address.

The primary address of your Model 199 is set to 26 at the factory, but you can program other values between 0 and 30 by pressing 199 SETUP.

More detailed information on primary address selection is located in paragraph 3.5.

Step 3: Write Your Program

Even the most basic operations will require that you write a simple program to send commands and read back data from the instrument. Figure 3-1 shows a basic flow chart that a typical simple program will follow. The programming example below follows this general sequence. This program will allow you to type in command strings to program the instrument and display data on the computer CRT.

HP BASIC 4.0 Programming Example—Use the simple program below to send programming commands to the Model 199 and display the data string on the computer CRT.

PROGRAM	COMMENTS
`10 REMOTE 726`	Send remote enable.
`20 PRINT ''COMMAND'';`	Prompt for command string.
`30 INPUT C$`	Input the command string.
`40 OUTPUT 726; C$`	Send command string to 199
`50 ENTER 726; A$`	Get a reading from the instrument.
`60 PRINT A$`	Display the reading.
`70 GOTO 20`	Repeat.
`80 END`	

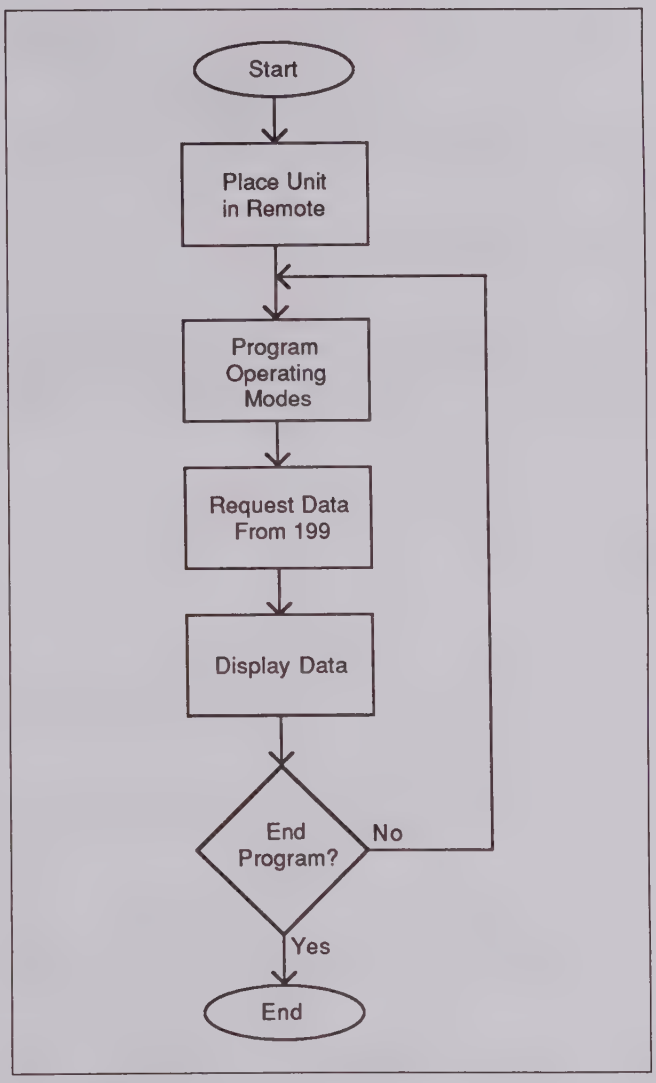


Figure 3-1. Typical Program Flow Chart

Step 4: Program Model 199 Operating Modes

You can program instrument operating modes by sending the appropriate command, which is made up of an ASCII letter representing the command, followed by a numeric parameter for the command option. Table 3-1 summarizes the commands used to select function and range.

A number of commands can be grouped together in one string, if desired. Also, you must terminate the command or command string with the X character in order for the instrument to execute the commands in question.

If you are using the programming example from Step 3 above, simply type in the command string when prompted to do so. Some example strings are given below.

F3X select DCA function.
F0R2X select DCV function, 3V range.

Step 5: Get Readings from the Model 199

Usually, you will want to obtain one or more readings from the Model 199. In the example program above, a single reading is requested and displayed after each command. In other cases, you may wish to program the instrument configuration at the beginning of your program, and then obtain a whole series of measurements.

The basic reading string that the Model 199 sends over the bus is in ASCII characters of the form:

NDCV–1.23456E+0

where: N indicates a normal reading (O would indicate an overflow),
DCV shows the function in effect (in this case, DC volts)
–1.23456 is the mantissa of the reading data,
E+0 represents the exponent.

Table 3-1. IEEE-488 Commands Used to Select Function and Range

Mode	Command	Description						
Execute	X	Execute other device-dependent commands.						
Function	F0	DC volts						
	F1	AC volts						
	F2	Ohms						
	F3	DC current						
	F4	AC current						
	F5	ACV dB						
	F6	ACA dB						
Range		DCV	ACV	DCA	ACA	Ohms	ACV dB	ACA dB
	R0	Auto	Auto	Auto	Auto	Auto	Auto	Auto
	R1	300mV	300mV	30mA	30mA	300 Ω	Auto	Auto
	R2	3 V	3 V	3 A	3 A	3 kΩ	Auto	Auto
	R3	30 V	30 V	3 A	3 A	30 kΩ	Auto	Auto
	R4	300 V	300 V	3 A	3 A	300 kΩ	Auto	Auto
	R5	300 V	300 V	3 A	3 A	3MΩ	Auto	Auto
	R6	300 V	300 V	3 A	3 A	30MΩ	Auto	Auto
	R7	300 V	300 V	3 A	3 A	300MΩ	Auto	Auto

3.3 BUS CONNECTIONS

The Model 199 is intended to be connected to the IEEE-488 bus through a cable equipped with standard IEEE-488 connectors, an example of which is shown in Figure 3-2. The connector is designed to be stacked to allow a number of parallel connections at one instrument. Two screws are located on each connector to ensure that connections remain secure. Current standards call for metric threads, which are identified with dark colored screws. Earlier versions had different screws, which were silver colored. Do not attempt to use these type of connectors on the Model 199, which is designed for metric threads.

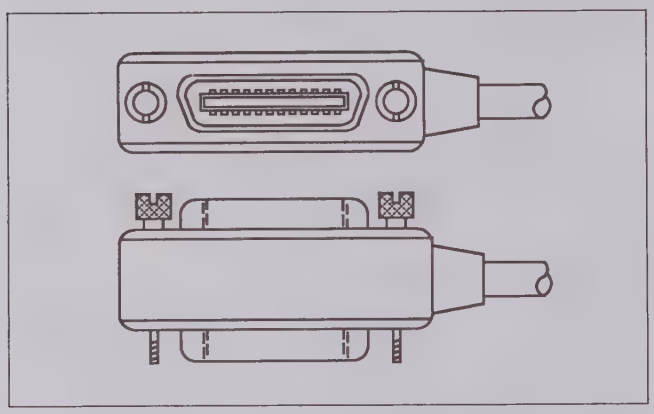


Figure 3-2. IEEE-488 Connector

A typical connecting scheme for a multiple-instrument test set up is shown in Figure 3-3. Although any number of connectors can be stacked on one instrument, it is recommended that you stack no more than three connectors on any one unit to avoid possible mechanical damage.

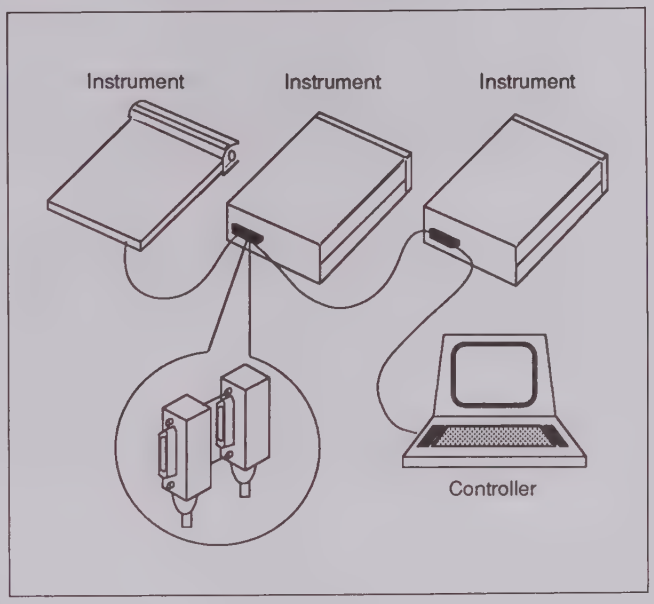


Figure 3-3. IEEE-488 Connections

Connect the Model 199 to the IEEE-488 bus as follows:

1. Line up the cable connector with the connector located on the rear panel of the instrument. The connector is designed so that it will fit only one way. Figure 3-4 shows the location of the IEEE-488 connector on the instrument.
2. Tighten the screws securely, but do not overtighten them.
3. Add additional connectors from other instruments, as required.
4. Make certain that the other end of the cable is properly connected to the controller. Most controllers are equipped with an IEEE-488 style connector, but a few may require a different type of connecting cable. Consult the instruction manual for your controller for the proper connecting method.

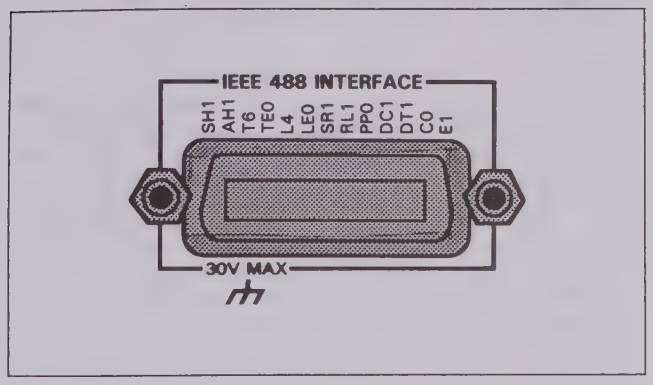


Figure 3-4. IEEE-488 Connector Location

NOTE

The IEEE-488 bus is limited to a maximum of 15 devices, including the controller. The maximum cable length is 20 meters, or 2 meters times the number of devices, which ever is less. Failure to observe these limits may result in erratic bus operation.

Custom cables may be constructed by using the information in Table 3-2 and Figure 3-5. Table 3-2 lists the contact assignments for the bus, and Figure 3-5 shows the contact configuration.

CAUTION

IEEE-488 common is connected to digital common. Maximum voltage between digital common and earth ground is 30V.

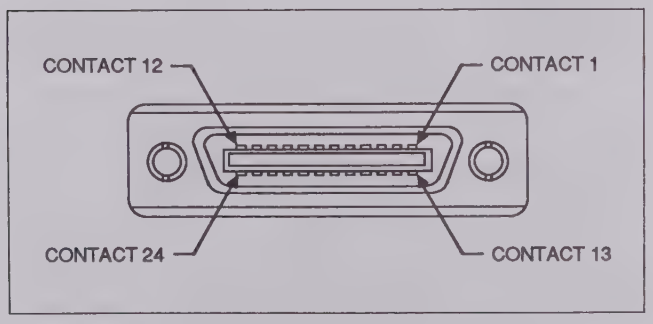


Figure 3-5. Contact Assignments

Table 3-2. IEEE Contact Designations

Contact Number	IEEE-488 Designation	Type
1	DIO1	Data
2	DIO2	Data
3	DIO3	Data
4	DIO4	Data
5	EOI (24)*	Management
6	DAV	Handshake
7	NRFD	Handshake
8	NDAC	Handshake
9	IFC	Management
10	SRQ	Management
11	ATN	Management
12	SHIELD	Ground
13	DIO5	Data
14	DIO6	Data
15	DIO7	Data
16	DIO8	Data
17	REN (24)*	Management
18	Gnd, (6)*	Ground
19	Gnd, (7)*	Ground
20	Gnd, (8)*	Ground
21	Gnd, (9)*	Ground
22	Gnd, (10)*	Ground
23	Gnd, (11)*	Ground
24	Gnd, LOGIC	Ground

*Numbers in parentheses refer to signal ground return of referenced contact number. EOI and REN signal lines return on contact 24.

3.4 INTERFACE FUNCTION CODES

The interface function codes, which are part of the IEEE-488 standards, define an instrument's ability to support various interface functions, and they should not be confused with programming commands found elsewhere in this manual. Interface function codes for the Model 199 are listed in Table 3-3 and are listed for convenience on the rear panel adjacent to the IEEE-488 connector. The codes define Model 199 capabilities as follows:

SH (Source Handshake)—SH1 defines the ability of the Model 199 to properly handshake data or command bytes when the unit is acting as a source.

AH (Acceptor Handshake)—AH1 defines the ability of the Model 199 to properly handshake the bus when it is acting as an acceptor of data or commands.

T (Talker)—The ability of the Model 199 to send data over the bus to other devices is defined by the T function. Model 199 talker capabilities exist only after the instrument has been addressed to talk.

L (Listener)—The L function defines the ability of the Model 199 to receive device-dependent data over the bus. Listener capabilities exist only after the instrument has been addressed to listen.

SR (Service Request)—The SR function defines the ability of the Model 199 to request service from the controller.

RL (Remote-Local)—The RL function defines the capability of the Model 199 to be placed in the remote or local modes.

PP (Parallel Poll)—The Model 199 does not have parallel polling capabilities.

DC (Device Clear)—The DC function defines the ability of the Model 199 to be cleared (initialized).

DT (Device Trigger)—The ability for the Model 199 to have its readings triggered is defined by the DT function.

C (Controller)—The Model 199 does not have controller capabilities.

TE (Extended Talker)—The Model 199 does not have extended talker capabilities.

LE (Extended Listener)—The Model 199 does not have extended listener capabilities.

E (Bus Driver Type)—The Model 199 has open-collector bus drivers.

Table 3-3. Model 199 Interface Function Codes

Code	Interface Function
SH1	Source Handshake capability
AH1	Acceptor Handshake capability
T6	Talker (Basic talker, Serial poll, Unaddressed to talk on LAG)
L4	Listener (Basic listener, Unaddressed to listen on TAG)
SR1	Service Request capability
RL1	Remote/Local capability
PP0	No Parallel Poll capability
DC1	Device Clear capability
DT1	Device Trigger capability
C0	No Controller capability
E1	Open Collector Bus Drivers
TE0	No Extended Talker capabilities
LE0	No Extended Listener capabilities

3.5 PRIMARY ADDRESS SELECTION

The Model 199 must receive a listen command before it will respond to addressed commands over the bus. Similarly, the instrument must receive a talk command before it will transmit its data. These listen and talk commands are derived from the primary address of the instrument, which is set to 26 at the factory. Until you become more familiar with your instrument, it is recommended that you leave the address at this value because the programming examples in this manual assume the instrument is programmed for that address.

The primary address can be programmed for any value between 0 and 30. However, each device on the bus must have a unique primary address-- a factor that should be kept in mind when setting the primary address of the Model 199. Most controllers also use a primary address; consult the controller instruction manual for details. Whatever address is used, it must be the same as the value specified as part of the controller's programming language.

To check the presently programmed primary address, or to change to a new one, proceed as follows:

1. Press SHIFT DMM SETUP then NEXT. The current primary address will be displayed. For example, if the current address is 26, the following message will be displayed:

   26 IEEE

2. To modify the address, key in a new value (0-30) with the numeric data buttons.
3. To return to normal operation without permanently changing the address, press NEXT six times in succession.
4. To store the address as the power up address, first press NEXT twice, then use uprange to display "SAVE YES." Press NEXT three times to return to normal operation.

3.6 CONTROLLER PROGRAMMING

A number of IEEE-488 controllers are available, each of which has its own programming language. In this section, we will discuss the programming language for the Hewlett-Packard Series 200 and 300 (BASIC 4.0).

3.6.1 Controller Handler Software

Before a specific controller can be used over the IEEE-488 bus, it must have IEEE-488 handler software installed. With some controllers, the software is located in an optional I/O ROM, and no software installation is necessary on the part of the user. In other cases, software must be loaded from a diskette and initialized.

Other small computers that can be used as IEEE-488 controllers may not support all IEEE-488 functions. With some, interface programming may depend on the particular interface being used. Many times, little "tricks" are necessary to obtain the desired results.

From the preceding discussion, the message is clear: make sure the proper software is being used with the interface. Often the user may incorrectly suspect that the hardware is causing a problem, when it was the software all along.

3.6.2 BASIC Interface Programming Statements

The programming instructions covered in this section include examples written in Hewlett-Packard BASIC 4.0. This computer language was chosen for the examples because of its versatility in controlling the IEEE-488 bus. A partial list of statements for BASIC 4.0 is shown in Table 3-4.

Statements have a one or three digit argument that must be specified as part of the statement. The first digit is the interface select code, which is set to 7 at the factory. The last two digits of those statements requiring a 3-digit argument specify the primary address. In the examples shown, the default Model 199 address (26) is shown. For a different address, you would of course change the corresponding digits in the programming statement.

Some of the statements have two forms, with the exact configuration depending on the command to be sent over the bus. For example, CLEAR 7 sends a DCL command over the bus, while CLEAR 726 sends the SDC command to a device with a primary address of 26.

Table 3-4. BASIC Statements Necessary to Send Bus Commands

Action	HP-85 Statement
Transmit string to device 26.	OUTPUT 726; A$
Obtain string from device 26.	ENTER 726; A$
Send GTL to device 26.	LOCAL 726
Send SDC to device 26.	CLEAR 726
Send DCL to all devices.	CLEAR 7
Send remote enable.	REMOTE 7
Cancel remote enable.	LOCAL 7
Serial poll device 26.	SPOLL (726)
Send Local Lockout.	LOCAL LOCKOUT 7
Send GET to device.	TRIGGER 726
Send IFC.	ABORT 7

3.7 FRONT PANEL ASPECTS OF IEEE-488 OPERATION

The following paragraphs discuss aspects of the front panel that are part of IEEE-488 operation, including front panel error messages, IEEE-488 status indicators, and the LOCAL key.

3.7.1 Front Panel Error Messages

The Model 199 has a number of front panel error messages associated with IEEE-488 programming. These messages are intended to inform you of certain conditions that may occur when sending device-dependent commands to the instrument, as summarized in Table 3-5.

The following paragraphs discuss each of these messages in detail. Note that the instrument may be programmed to generate an SRQ (paragraph 3.9.13), and the U1 error word can be checked for specific error conditions (paragraph 3.9.16) if any of these errors occur.

Table 3-5. Front Panel IEEE-488 Messages

Message	Description
NO REMOTE	Instrument programmed with REN false.
IDDC	Illegal Device-dependent Command
IDDCO	Illegal Device-dependent Command Option
TRIGGER OVERRUN	Instrument triggered while it is still processing a previous trigger.
INTERVAL OVERRUN	Instrument cannot store readings at programmed interval. Readings will be stored as fast as the instrument can run.
BIG STRING	Programmed display message exceeds 10 characters.
CAL LOCKED	Calibration command sent with calibration switch in the disable position.
CHAN 4 MAX*	Channel limit is 4 in 4-pole mode
CHAN 8 MAX*	Channel limit is 8 in 2-pole mode

*Scanner error messages. See paragraph 3.12.

NOTE: Error messages associated with translator software are located in paragraph 3.10.

No Remote Error

A no remote error will occur if the instrument receives a device-dependent command and the REN (Remote Enable) line is false. In this instance, the following error message will be displayed on the front panel:

NO REMOTE

The error condition can be corrected by placing the REN line true before attempting to program the instrument.

Programming Example—To demonstrate the NO REMOTE error message, type in the following lines:

```
LOCAL 7
OUTPUT 726; ''R1X''
```

Note that the NO REMOTE error message is briefly displayed when the second statement above is executed.

IDDC (Illegal Device-Dependent Command) Error

An IDDC error occurs when the unit receives an invalid command over the bus. For example, the command string E1X includes an illegal command because the letter E is not part of the instrument's programming language. When an illegal command is received, the instrument will briefly display the following error message:

IDDC

To avoid this error condition, send only valid commands. Refer to paragraph 3.9 for device-dependent command programming details.

Programming Example—To demonstrate an IDDC error, use the following statements:

```
REMOTE 726
OUTPUT 726; ''E1X''
```

Note that the IDDC error message is briefly displayed when the second statement above is executed.

IDDCO (Illegal Device-Dependent Command Option) Error

Sending the instrument a legal command with an illegal option will result in the following front panel error message:

IDDCO

For example, the command Y9X has an illegal option (9) that is not part of the instrument's programming language. Thus, although the command (Y) itself is valid, the option (9) is not, and the IDDCO error will result.

To avoid this error condition, use only valid command options, as discussed in paragraph 3.9.

Programming Example—Demonstrate an IDDCO error with the following statements:

```
REMOTE 726
OUTPUT 726; ''Y9X''
```

Note that the IDDCO error message is briefly displayed when the second statement above is executed.

Trigger Overrun Error

A trigger overrun error occurs when the instrument receives a trigger while still processing a reading from a previous trigger. Note that any overrun triggers are ignored. These overrun triggers will not affect the instrument except to generate the message below. When a trigger overrun occurs, the following front panel message will be displayed for approximately one second:

TRIGGER OVERRUN

Programming Example—To demonstrate a trigger overrun error, enter the following statements into the computer keyboard:

```
REMOTE 726
OUTPUT 726;''T5X''
OUTPUT 726;''XX''
```

Note that the trigger overrun message is displayed after the third statement is executed.

Big String Error

A big string error occurs when trying to display a message (using the D command) that exceeds 10 characters. Blank display digits used in the message count as characters. The invalid message is ignored and the following message is displayed briefly when a big string error occurs:

BIG STRING

Programming Example—Enter the following statements into the computer to demonstrate a big string error:

```
REMOTE 726
OUTPUT 726;''DH0W@ARE@YOU?X''
```

The big string error will occur because the message is made up of 12 characters.

Cal Locked Error

A cal locked error occurs when trying to calibrate the instrument over the bus with the front panel calibration switch in the disable position. Calibration commands will be ignored and the following message will be displayed briefly:

CAL LOCKED

Interval Overrun Error

A interval overrun error occurs when the instrument cannot store readings in the data store or scan at the programmed interval (Q command). However, the instrument will continue to store readings as fast as it can run. The following message is displayed briefly when a short time error occurs:

INTERVAL OVERRUN

Programming Example—To demonstrate an interval overrun error, enter the following statements into the computer:

```
REMOTE 726
OUTPUT 726;''Q15I100S1T2X''
TRIGGER 726
```

The instrument will start storing readings in the buffer. However, since the instrument cannot make measurements at the selected interval (15msec), interval overrun errors will occur.

3.7.2 IEEE-488 REMOTE Indicator and LOCAL Key

REMOTE—The REM indicator shows when the instrument is in the remote mode. Note that REM does not necessarily indicate the state of the REN line, as the instrument must be addressed to listen with REN true before the REM indicator will turn on. When the instrument is in remote, all front panel keys except for the LOCAL key will be locked out. When REM is turned off, the instrument is in the local mode.

LOCAL—The LOCAL key cancels the remote mode and restores local operation of the instrument.

Since all front panel keys except LOCAL are locked out when the instrument is in remote, this key provides a convenient method of restoring front panel operation. Pressing LOCAL will also turn off the REM indicator and return the display to the normal mode if user messages were previously displayed with the D command.

Note that the LOCAL key will also be inoperative if the LLO (Local Lockout) command is in effect.

3.8 GENERAL BUS COMMAND PROGRAMMING

General bus commands are those commands such as DCL that have the same general purpose regardless of the instrument. Commands supported by the Model 199 are summarized in Table 3-6, which lists BASIC 4.0 statements necessary to send each command. Note that commands requiring a primary address assume that the Model 199 primary address is set to 26 (its factory default address).

3.8.1 REN (Remote Enable)

REN is a uniline command that must be asserted by the controller to place the Model 199 in remote. Simply setting REN true will not actually place the instrument in remote; instead, the unit must be addressed to listen after REN is set true.

Generally, remote enable should be asserted before attempting to program the instrument over the bus. Once the instrument is in remote, all front panel controls except LOCAL will be inoperative. Normal front panel operation can be restored by pressing the LOCAL key.

To place the Model 199 in remote, the controller must perform the following sequence:

1. Set the REN line true.
2. Address the Model 199 to listen.

Programming Example—Place the Model 199 in remote with the following statement:

```
REMOTE 726
```

The Model 199 should be in remote, as indicated by the annunciator light. If not, check to see that proper bus connections are made, and that the instrument is programmed for the correct primary address (26).

Note that all front panel controls except LOCAL (and, of course, POWER) are inoperative while the instrument is in remote. You can restore normal front panel operation by pressing the LOCAL button.

3.8.2 IFC (Interface Clear)

The IFC command is sent by the controller to place the Model 199 in the talker and listener idle states. The unit will respond to the IFC command by cancelling TALK or LISTEN, if the instrument was previously placed in one of those modes.

To send the IFC command, the controller need only set the IFC line true for a minimum of 100μsec.

Table 3-6. General Bus Commands and Associated BASIC Statements

Command	BASIC 4.0 Statement	Affect on Model 199
REN	REMOTE 7	Goes into remote when next addressed.
IFC	ABORT 7	Goes into talker and listener idle states.
LLO	LOCAL LOCKOUT 7	Front LOCAL key locked out.
GTL	LOCAL 726	Cancel remote.
DCL	CLEAR 7	Returns to default conditions.
SDC	CLEAR 726	Returns to default conditions.
GET	TRIGGER 726	Triggers reading in T2 and T3 modes.

3.8.3 LLO (Local Lockout)

The LLO command is used to lock out operation of the LOCAL key, thereby completely locking out front panel operation of the instrument (recall that the remaining controls are locked out when the instrument is placed in remote).

To send the LLO command, the controller must perform the following steps:

1. Set ATN true.
2. Place the LLO command byte on the data bus.

To cancel local lockout and return control to the front panel, REN must be set false by sending the LOCAL 7 command to the instrument.

Programming Example—To verify LLO operation, enter the following statements:

```
REMOTE 726
LOCAL LOCKOUT 7
```

After the second statement is executed, the LOCAL key will be locked out.

To cancel LLO, type in the following statement:

```
LOCAL 7
```

When END LINE is pressed, control to the front panel will be restored.

3.8.4 GTL (Go To Local)

The GTL command is used to take the instrument out of the remote mode and restore operation of the front panel keys.

To send GTL, the controller must perform the following sequence:

1. Set ATN true.
2. Address the Model 199 to listen.
3. Place the GTL command byte on the data lines.

The GTL command will not cancel LLO (local lockout) since it does not set REN false.

Programming Example—Place the instrument in the remote mode with the following statement:

```
REMOTE 726
```

Verify that the instrument is in remote.

Send GTL as follows:

```
LOCAL 726
```

Note that the instrument goes into the local mode, and that operation of the front panel keys has now been restored.

3.8.5 DCL (Device Clear)

The DCL command may be used to clear the Model 199 and return it to its default conditions. Note that the DCL command is not an addressed command, so all instruments equipped to implement DCL will do so simultaneously. When the Model 199 receives a DCL command, it will return to default conditions (see paragraph 3.9.11). Table 3-7 lists factory default conditions.

Table 3-7. Factory Default Conditions

Mode	Command	Status
Multiplex*	A1	Enabled
Reading	B0	A/D converter
Function*	F0	DC volts
Data Format	G0	Send prefix with reading
Self-Test	J0	Clear
EOI	K0	Enable EOI and bus hold-off on X
SRQ	M0	Disabled
Filter*	P1	Internal enabled
Interval*	Q0	175msec (SELECT OFF)
Data Store Size*	I0	Continuous
Range*	R4	300V
Rate*	S1	5½d, line cycle integration
Trigger	T6	Continuous on external trigger
Delay*	W0	No delay
Terminator	Y0	CR LF
Zero	Z0	Disabled

*These defaults can be changed. See paragraph 3.9.11.

To send the DCL command, the controller must perform the following steps:

1. Set ATN true.
2. Place the DCL command byte on the data bus.

Notes:

1. DCL will return the instrument to the default line frequency setting.
2. DCL will not have any effect on the current IEEE address.

Programming Example—Place the unit in an operating mode that is not a default condition. Now enter the following statement into the keyboard:

```
CLEAR 7
```

Note that the instrument returns to the default conditions.

3.8.6 SDC (Selective Device Clear)

The SDC command is an addressed command that performs essentially the same function as the DCL command. However, since each device must be individually addressed, the SDC command provides a method to clear only a single, selected instrument instead of clearing all instruments simultaneously, as is the case with DCL. When the Model 199 receives the SDC command, it will return to the default conditions (see paragraph 3.9.11). Table 3-7 lists factory default conditions.

To transmit the SDC command, the controller must perform the following steps:

1. Set ATN true.
2. Address the Model 199 to listen.
3. Place the SDC command byte on the data bus.

Notes:

1. SDC will return the instrument to the default line frequency setting.
2. SDC will not have any effect on the current IEEE address.

Programming Example—Using several front panel controls, alter instrument states from the default configuration. Send SDC with the following statement:

```
CLEAR 726
```

When the above statement is executed, the instrument returns to the default configuration.

3.8.7 GET (Group Execute Trigger)

GET may be used to initiate a Model 199 measurement sequence if the instrument is placed in the appropriate trigger mode (see paragraph 3.9). Once triggered, the instrument will take a single reading or series of readings.

To send GET, the controller must perform the following sequence:

1. Set ATN low.
2. Address the Model 199 to listen.
3. Place the GET command byte on the data bus.

Programming Example—Type in the following statements to place the instrument in the correct trigger mode for purposes of this demonstration:

```
REMOTE 726
OUTPUT 726; ''T3X''
```

Now trigger the reading by sending GET with the following statement:

```
TRIGGER 726
```

The reading will be triggered when the statement is executed.

3.8.8 Serial Polling (SPE,SPD)

The serial polling sequence is used to obtain the Model 199 serial poll byte. The serial poll byte contains important information about internal functions, as described in paragraph 3.9.13. The serial polling sequence can also be used by the controller to determine which instrument on the bus has asserted SRQ (Service Request).

The serial polling sequence is generally conducted as follows:

1. The controller sets ATN true.
2. The controller then places the SPE (Serial Poll Enable) command byte on the data bus. At this point, all active devices are in the serial poll enabled mode and waiting to be addressed.
3. The Model 199 is then addressed to talk.
4. The controller sets ATN false.
5. The instrument places its serial poll byte on the data bus to be read by the controller.
6. The controller then sets ATN true and places the SPD (Serial Poll Disable) command byte on the data bus to end the serial polling sequence.

Once instruments are in the serial poll mode, steps 3 through 5 above can be repeated by sending the correct talk address for each instrument.

Programming Example—The SPOLL statement automatically performs the sequence just described. To demonstrate serial polling, type in the following program lines:

```
10 REMOTE 726
20 S= SPOLL (726)
30 PRINT S
40 END
```

When the above program is executed, the Model 199 is serial polled, and the decimal value of the serial poll byte is displayed on the computer CRT.

3.9 DEVICE-DEPENDENT COMMAND PROGRAMMING

IEEE-488 device-dependent commands are used with the Model 199 to control various operating modes such as function, range, trigger mode and data format. Each command is made up of a single ASCII letter followed by a number representing an option of that command. For example, a command to control the measuring function is programmed by sending an ASCII "F" followed by a number representing the function option.

A number of commands may be grouped together in one string. A command string is usually terminated with an ASCII "X" character, which tells the instrument to execute the command string. Commands sent without the execute character will not be executed at that time, but they will be retained within an internal command buffer for execution at the time the X character is received. If any errors occur, the instrument will display appropriate front panel error messages and generate an SRQ if programmed to do so.

Commands that affect instrument operation will trigger a reading when the command is executed. These bus commands affect the Model 199 much like the front panel controls. Note that commands are not necessarily executed in the order received; instead, they will be executed in alphabetical order. Thus to force a particular command sequence, you would follow each command with the execute character (X), as in the example string, L0XF2X, which will reset the instrument to factory default conditions and then select the ohms function.

Device-dependent commands can be sent either one at a time, or in groups of several commands within a single string. Some examples of valid command strings include:

F0X—Single command string.
F0K1P0R0X—Multiple command string.
T6 X—Spaces are ignored.

Typical invalid command strings include:

E1X—Invalid command, as E is not one of the instrument commands.
F15X—Invalid command option because 15 is not an option of the F command.

If an illegal command (IDDC), illegal command option (IDDCO), is sent, or if a command string is sent with REN false, the string will not be executed.

Device-dependent commands that control the Model 199 itself are listed in Table 3-8 (Scanner programming is covered separately in paragraph 3.12). These commands are covered in detail in the following paragraphs. The associated programming examples show how to send the commands from BASIC 4.0.

Notes:

1. Programming examples assume that the Model 199 is at its factory default value of 26.
2. Device dependent commands sent over the bus while the unit is in a front panel menu will be ignored. Before programming over the bus, press NEXT as many times as necessary to exit the menu.

In order to send a device-dependent command, the controller must perform the following steps:

1. Set ATN true.
2. Address the Model 199 to listen.
3. Set ATN false.
4. Send the command string over the bus one byte at a time.

Table 3-8. Device-Dependent Command Summary

Mode	Command	Description	Paragraph
Execute	X	Execute other device-dependent commands.	3.9.1
Function	F0 F1 F2 F3 F4 F5 F6	DC volts AC volts Ohms DC current AC current ACV dB ACA dB	3.9.2
Range			3.9.3

	DCV	ACV	DCA	ACA	Ohms	ACV dB	ACA dB
R0	Auto	Auto	Auto	Auto	Auto	Auto	Auto
R1	300mV	300mV	30mA	30mA	300 Ω	Auto	Auto
R2	3 V	3 V	3 A	3 A	3 kΩ	Auto	Auto
R3	30 V	30 V	3 A	3 A	30 kΩ	Auto	Auto
R4	300 V	300 V	3 A	3 A	300 kΩ	Auto	Auto
R5	300 V	300 V	3 A	3 A	3MΩ	Auto	Auto
R6	300 V	300 V	3 A	3 A	30MΩ	Auto	Auto
R7	300 V	300 V	3 A	3 A	300MΩ	Auto	Auto

Zero	Z0 Z1 Z2	Zero disabled Zero enabled Zero enabled using a zero value (V)	3.9.4
Filter	P0 P1 P2	Internal and front panel filter disabled Internal filter enabled Front panel filter enabled	3.9.5
Rate	S0 S1	4½ digit resolution, 2.59msec integration period 5½ digit resolution, line cycle integration (16.67msec, 60Hz; 20msec, 50Hz)	3.9.6
Trigger Mode	T0 T1 T2 T3 T4 T5 T6 T7	Continuous on Talk One-shot on Talk Continuous on GET One-shot on GET Continuous on X One-shot on X Continuous on External Trigger One-shot on External Trigger	3.9.7
Reading Mode	B0 B1 B2	Readings from A/D converter Individual readings from data store All readings from data store (buffer dump)	3.9.8
Data Store Size	I0 In	Wrap around data store mode Data store of n (n=1 to 500)	3.9.9

Table 3-8. Device-Dependent Command Summary (Cont.)

Mode	Command	Description	Paragraph
Interval	Q0 Qn	Default interval, 175msec (SELECT OFF) n=interval in milliseconds (15msec to 999999msec)	3.9.9
Value	V±nn.nnnn or V±n.nnnnnnE+n	Calibration value, zero value	3.9.10
Calibration	C0 C1 C2	Calibrate first point using value (V) Calibrate second point using value (V) Calibrate third point using value (V)	3.9.10
Default Conditions	L0 L1	Restore factory default conditions and save (L1) Save present machine states as default conditions	3.9.11
Data Format	G0 G1 G2 G3 G4 G5 G6 G7	Reading with prefix. Reading without prefix. Reading and buffer location with prefix. Reading and buffer location without prefix. Reading and channel with prefix. Reading and channel without prefix. Reading, buffer location, and channel with prefix Reading, buffer location, and channel without prefix	3.9.12
SRQ	M0 M1 M2 M4 M8 M16 M32	Disable Reading overflow Data store full Data store half full Reading done Ready Error	3.9.13
EOI and Bus Hold-off	K0 K1 K2 K3	Enable EOI and bus hold-off on X Disable EOI, enable bus hold-off on X Enable EOI, disable bus hold-off on X Disable both EOI and bus hold-off on X	3.9.14
Terminator	Y0 Y1 Y2 Y3	CR LF LF CR CR LF	3.9.15
Status	U0 U1 U2 U3 U4 U5	Send machine status word Send error conditions Send Translator word list Send buffer size Send current value of "V" Send input switch status (front/rear)	3.9.16
Multiplex	A0 A1	Auto/Cal multiplex disabled Auto/Cal multiplex enabled	3.9.17
Delay	Wn	n=delay period in milliseconds, (0msec to 999999msec)	3.9.18
Self-test	J0	Test, ROM, RAM, E²PROM	3.9.19
Hit Button	Hn	Hit front panel button number n	3.9.20
Display	Da D	Display up to 10 character message. a=character Cancel display mode	3.9.21

NOTES:

1. REN must be true when sending device-dependent commands to the instrument, or it will ignore the command and display a bus error message.
2. Scanner programming commands are covered in paragraph 3.12.

General Programming Example—Device-dependent commands may be sent from the computer with the following statement:

```
OUTPUT 726;A$
```

A$ in this case contains the ASCII characters representing the command string.

3.9.1 Execute (X)

The execute command is implemented by sending an ASCII "X" over the bus. Its purpose is to direct the Model 199 to execute other device-dependent commands such as F (function) or R (range). Usually, the execute character is the last byte in the command string (a number of commands may be grouped together into one string); however, there may be certain circumstances where it is desirable to send a command string at one time, and then send the execute character later on. Command strings sent without the execute character will be stored within an internal command buffer for later execution. When the X character is finally transmitted, the stored commands will be executed, assuming that all commands in the previous string were valid.

Programming Example—Enter the following statements into the keyboard:

```
REMOTE 726
OUTPUT 726;''X''
```

The X character will be transmitted to the instrument. No mode changes will occur with this example because no other commands were sent. Note that the instrument remains in the listener active state after the command is transmitted.

3.9.2 Function (F)

The function command allows the user to select the type of measurement made by the Model 199. When the instrument responds to a function command, it will be ready to take a reading once the front end is set up. The function may be programmed by sending one of the following commands:

F0 = DC Volts
F1 = AC Volts
F2 = Ohms
F3 = DC Current
F4 = AC Current
F5 = ACV dB
F6 = ACA dB

Upon power up, or after the instrument receives a DCL or SDC command, the Model 199 will return to the default condition.

Programming Example—Place the instrument in the ohms function by pressing the OHMS button and enter the following statements into the computer keyboard:

```
REMOTE 726
OUTPUT 726;''F0X''
```

When F0X is executed, the instrument changes to DC volts.

3.9.3 Range (R)

The range command gives the user control over the sensitivity of the instrument. This command, and its options, perform essentially the same functions as the front panel Range buttons. Range command parameters and the respective ranges for each measuring function are summarized in Table 3-9. The instrument will be ready to take a reading after the range is set up when responding to a range command.

Upon power up, or after the instrument receives a DCL or SDC command, the Model 199 will return to the default condition.

Programming Example—Make sure the instrument is in the autorange mode and then enter the following statements into the computer:

```
REMOTE 726
OUTPUT 726;''R3X''
```

Table 3-9. Range Command Summary

	Range						
Command	DCV	ACV	DCA	ACA	Ohms	ACV dB	ACA dB
R0	Auto	Auto	Auto	Auto	Auto	Auto	Auto
R1	300mV	300mV	30mA	30mA	300 Ω	Auto	Auto
R2	3 V	3 V	3 A	3 A	3 kΩ	Auto	Auto
R3	30 V	30 V	3 A	3 A	30 kΩ	Auto	Auto
R4	300 V	300 V	3 A	3 A	300 kΩ	Auto	Auto
R5	300 V	300 V	3 A	3 A	3MΩ	Auto	Auto
R6	300 V	300 V	3 A	3 A	30MΩ	Auto	Auto
R7	300 V	300 V	3 A	3 A	300MΩ	Auto	Auto

The instrument cancels the autorange mode, and enters the R3 range instead.

3.9.4 Zero (Z)

Over the bus, the zero modifier can be controlled in the same way that it is controlled from the front panel. Refer to paragraph 2.6.2 for a complete description of the zero modifier. The zero modifier is controlled by sending one of the following zero commands over the bus:

Z0 = Zero disabled.
Z1 = Zero enabled.
Z2 = Zero enabled using a zero value (V).

Sending Z1 has the same effect as pressing the ZERO button. Zero will enable, and the display will zero with the input signal becoming the zero baseline level.

The Z2 command is used when a zero value, using the V command, has already been established. When the Z2 command is sent, subsequent readings represent the difference between the input signal and the value of V. For example, with 0.5V on the input, sending the command strings V2XZ2X will result with zero being enabled and the instrument reading −1.5V (0.5 −2.0 = −1.5). If no V is value is programmed, a value of 0 is assumed.

NOTE

In a one-shot trigger mode, you must trigger the unit after sending the Z command to complete zero programming. ZERO will flash after sending Z1 until the unit is triggered.

Upon power up or after the instrument receives a DCL or SDC command, the Model 199 will return to the default condition.

Programming Example—Set the instrument to the 3V DC range. With the front panel ZERO button disable the zero mode, if enabled, and enter the following statements into the HP-85 keyboard:

```
REMOTE 726
OUTPUT 726;''V1X''
OUTPUT 726;''Z1X''
```

After the third statement, the ZERO indicator will turn on with a zero baseline of 1VDC.

3.9.5 Filter (P)

The filter command controls the amount of filtering applied to the input signal. The Model 199 filters the signal by taking the average of a number of successive reading samples. Since noise is mostly random in nature, it can be largely cancelled out with this method. Paragraph 2.6.3 discusses filtering in more detail.

P0 = No filtering
P1 = Internal filter enabled
P2 = Front panel filter enabled

Upon power up or after the instrument receives a DCL or SDC command, the Model 199 will return to the default condition.

Programming Example—With the front panel FILTER indicator off, enter the following statements into the computer.

```
REMOTE 726
OUTPUT 726;''P2X''
```

The filter will turn on.

3.9.6 Rate (S)

The rate command controls the integration period and the usable resolution of the Model 199. Table 3-10 lists the usable resolution on each function for the two S modes. The integration period is dependent on usable resolution as shown in Table 3-10.

Upon power up or after the instrument receives a DCL or SDC command, the Model 199 will return to the default condition.

Programming Example—From the front panel, set the display of the Model 199 for DCV at 4½d resolution. Now enter the following statements into the computer:

```
REMOTE 726
OUTPUT 726;''S1X''
```

When END LINE is pressed the second time, the S1 rate will be selected (5½ digit resolution).

Table 3-10. Rate Command Summary

Command	Resolution	Integration Period
S0	4½d	2.59msec
S1	5½d	Line*

*20msec @ 50Hz, 16.67msec @ 60Hz.

3.9.7 Trigger Mode (T)

Triggering provides a stimulus to begin a reading conversion within the instrument. Triggering may be done in two basic ways: in a continuous mode, a single trigger command is used to start a continuous series of readings; in a one-shot trigger mode, a separate trigger stimulus is required to start each conversion. The Model 199 has eight trigger commands as follows:

T0 = Continuous on Talk
T1 = One-shot on Talk
T2 = Continuous on GET
T3 = One-shot on GET
T4 = Continuous on X
T5 = One-shot on X
T6 = Continuous on External Trigger
T7 = One-shot on External Trigger

The trigger modes are paired according to the type of stimulus that is used to trigger the instrument. In the T0 and T1 modes, triggering is performed by addressing the Model 199 to talk. In the T2 and T3 modes, the IEEE-488 multiline GET command performs the trigger function. The instrument execute (X) character provides the trigger stimulus in the T4 and T5 modes. External trigger pulses provide the trigger stimulus in the T6 and T7 modes.

Upon power up or after the instrument receives a DCL or SDC command, the Model 199 will return to the default condition.

NOTES:

1. The front panel TRIGGER button can be used to trigger readings. See paragraph 2.8 for details.
2. In T6, the unit provides its own trigger.

Programming Example—Place the instrument in the one-shot on talk mode with the following program:

```
10 REMOTE 726
20 OUTPUT 726;''T1X''
30 ENTER 726;A$
40 PRINT A$
50 END
```

In this example, the ENTER statement addresses the Model 199 to talk, at which point a single reading is triggered. When the reading has been processed, it is sent out over the bus to the computer, which then displays the result.

3.9.8 Reading Mode (B)

The reading mode command parameters allow the selection of the source of data that is transmitted over the IEEE-488 bus. Through this command, the user has a choice of data from the A/D converter (normal DMM readings) or the buffer (data store). The reading mode commands are as follows:

B0 = A/D converter readings
B1 = Single Data Store readings
B2 = All Data Store readings

Upon power up or after the instrument receives a DCL or SDC command, the Model 199 will return to the default condition.

When in B0, normal A/D readings will be sent. In a continuous trigger mode, readings will be updated at the conversion rate. The B1 command is used to access single readings from the buffer. When the B1 command is sent, subsequent readings will be taken from consecutive buffer locations beginning with the first memory location (001). Once all readings have been requested, the last location will be continuously sent.

The B2 command allows you to dump the entire data store contents to the computer in one operation. Individual readings will be separated by commas, and the selected data format will apply to each reading. Data fields not applicable to the requested operation will be filled with zeroes. Also, the programmed terminator and EOI will be asserted at the end of the complete dump--not after each reading as is the case with the B1 mode.

NOTE

In B1 or B2 nothing will be transmitted over the bus until data is stored in data store.

Programming Example—Enter the following statements into the computer to send a reading over the bus and display it on the computer CRT.

```
10 REMOTE 726
20 OUTPUT 726;''B0X''
30 ENTER 726; A$
40 PRINT A$
50 END
```

The second statement above sets the instrument to the A/D converter reading mode. The third and fourth statements acquire the reading and display it on the CRT.

3.9.9 Data Store Interval (Q) and Size (I)

The data store is controlled by the interval command (Q) and the size command (I).

Interval

With the Q command, the user can select the interval that the instrument will store readings. The Q command is in the following form:

Q0=175msec default interval (SELECT OFF)
Qn=Set interval in millisec (15msec to 999999msec).

Note that the programmed interval also affects the interval between readings, and scan interval.

To store readings at a selected interval (Qn), the instrument must be in a continuous trigger mode (T0, T2, T4, T6). When the selected trigger occurs, the storage process will commence.

One-Shot Trigger Into Data Store

To use the data store in the one-shot mode, the instrument must be in a one-shot trigger mode (T1, T3, T5 or T7). In the T1 mode, one reading will be stored each time the instrument is addressed to talk. In the T3 mode, each GET command will cause one reading to be stored. In the T5 mode, each instrument execute character (X) will cause a reading to be stored. Finally, in the T7 mode, each external trigger pulse will cause a reading to be stored.

Size

The size of the data store can be controlled by one of the following I commands.

I0=Wrap around storage mode.
In=Set data store size to n (1 to 500).

In the wrap around data storage mode (I0), storage will not stop after the buffer is filled (500 readings), but will proceed back to the first memory location and start overwriting data. With the Innn command, the storage process will stop when the defined number of readings have been stored. In this case the buffer is considered to be full.

```
10 REMOTE 726
20 OUTPUT 726;''B0XG1X''
30 ENTER 726;A$
40 PRINT A$
50 END
```

NOTES:

1. Sending the I command enables data store; however, the unit must be properly triggered to begin storage once data store is enabled.
2. When the I command is sent, "------" will be displayed until the first trigger occurs.
3. The data store can be disabled by sending the F command.
4. The INTERVAL OVERRUN error message indicates that the instrument cannot store readings at the programmed interval rate. Instead, readings will be stored as fast as the instrument can run.
5. Either during or after the storage process, readings may be recalled by using the B1 or B2 command as described in the previous paragraph.

Upon power up or after the instrument receives a DCL or SDC command, the Model 199 will return to the default condition.

Programming Example—Enter the program below to enable data store operation and obtain and display 100 readings on the computer CRT:

PROGRAM	COMMENTS
`10 DIM A$[25]`	
`20 REMOTE 726`	Send remote enable.
`30 OUTPUT 726;` `''T20300I100X''`	Set trigger mode, and storage parameters.
`40 TRIGGER 726`	Start storage process.
`50 OUTPUT 726;` `''B1G2X''`	Set read mode to data store.
`60 FOR I=1 TO 100`	Set counter for 100 loops.
`70 ENTER 726;A$`	Get a reading.
`80 PRINT A$`	Display reading.
`90 NEXT I`	Loop back for next reading.
`100 END`	

After entering the program, press the RUN key. The program will set the store size to 100 (line 30), enable the data store (line 40), turn on the data store output (line 50), and then request and display all 100 readings (lines 60-100).

3.9.10 Value (V) and Calibration (C)

One advanced feature of the Model 199 is its digital calibration capabilities. Instead of the more difficult method of adjusting a number of potentiometers, the user need only apply an appropriate calibration signal and send the calibration value over the bus.

The V command is also used to program a zero value (see paragraph 3.9.4).

The value command may take on either of the following forms:

Vnn.nnnnn
Vn.nnnnnnE+n

Thus, the following two commands would be equivalent:

V30
V3.0E+1

In this example, note that only as many significant digits as necessary need be sent. In this case, the exact value is assumed to be 30.0000 even though only the first two digits were actually sent.

Digital Calibration—When performing digital calibration, two (three for DCV) points must be calibrated on each range. The first calibration value should be approximately full range and the second calibration value should be approximately zero. (The third point is at minus full range for DCV only). After the second or third calibration value is sent over the bus, permanent storage of the two values will occur.

In order to send calibration values over the bus, the calibration command (C) must be sent after the value command (V) is sent. The calibration command takes on the following form:

C0=Calibrate first point using value (V)
C1=Calibrate second point using value (V)
C2=Calibrate third point using value (V)

The following example first sends a calibration value of 3 and then a calibration of 0.

V3XC0X
V0XC1X

If the calibration value is greater than 303000 counts (at 5½d resolution) an IDDCO error message will be displayed on the Model 199.

CAUTION

Precision calibration signals must be connected to the instrument before attempting calibration, otherwise instrument accuracy will be affected. See Section 6 for complete details on calibrating the instrument either from the front panel or over the bus.

3.9.11 Default Conditions (L)

The L0 command allows the user to return the instrument to the factory default conditions. Factory default conditions are set at the factory and are listed in Tables 3-7 and 2-1. The instrument will power up to these default conditions. The current IEEE address and line frequency setting of the instrument are not affected by the L0 command.

The L1 command is used to save the current instrument conditions. The instrument will then power up to these default conditions.

Any of the options of the following device-dependent commands can be saved as the default conditions:

A (multiplex), F (function), P (Filter), Q and I (reading interval and size), R (range), S (rate), W (trigger delay), and Z (zero).

The L command options are as follows:

L0=Restore instrument to factory default conditions and save (L1).
L1=Save present machine states as the default conditions.

Programming Example—Set the Model 199 to the ohms function, and enable zero and filter. Now, enter the following statements into the computer:

```
REMOTE 726
OUTPUT 726;''L1X''
```

After the second statement, cycle power on the Model 199 and note that the instrument returns to the conditions initially set in this example.

3.9.12 Data Format (G)

The G command controls the format of the data that the instrument sends over the bus. Readings may be sent with or without prefixes. Prefixes are the mnemonics preceding the reading and the buffer memory location. Figure 3-6 further clarifies the general data format. The G commands are as follows:

G0 = Reading with prefix only. Example: NDCV−1.234567E+0
G1 = Reading without prefix. Example: −1.234567E+0
G2 = Reading and buffer memory location with prefix. Example: NDCV−1.234567E+0,B001
G3 = Readings and buffer memory without prefix. Example: −1.234567E+0,001.
G4 = Reading and channel with prefix. Example: NDC−1.234567E+0,C1
G5 = Reading and channel without prefix. Example: −1.234567E+0,1
G6 = Reading memory buffer location, and channel with prefix. Example: NDCV−1.234567E+0,B001,C1
G7 = Reading buffer memory location, and channel without prefix. Example: −1.234567E+0,001,01

Upon power up or after the instrument receives a DCL or SDC command, the Model 199 will return to the default condition.

Notes:

1. The B command affects the source of the data. In the B0 mode, the bus data will come from the A/D converter. In the B1 and B2 modes, the data will come from the buffer.
2. Programmed terminator and EOI sequences appear at the end of each reading except in B2 which terminates only at the end of the string.
3. If a buffer location or channel is not available, zero is sent. G6 Example: NDCV+2.000000E+1,B000,C0.
4. All 9s appear in the data field for an overflow.

Programming Example—To place the instrument in the G1 mode and obtain a reading, enter the following statements into the keyboard:

```
10 REMOTE 726
20 OUTPUT 726; ''B0XG1X''
30 ENTER 726;A$
40 PRINT A$
50 END
```

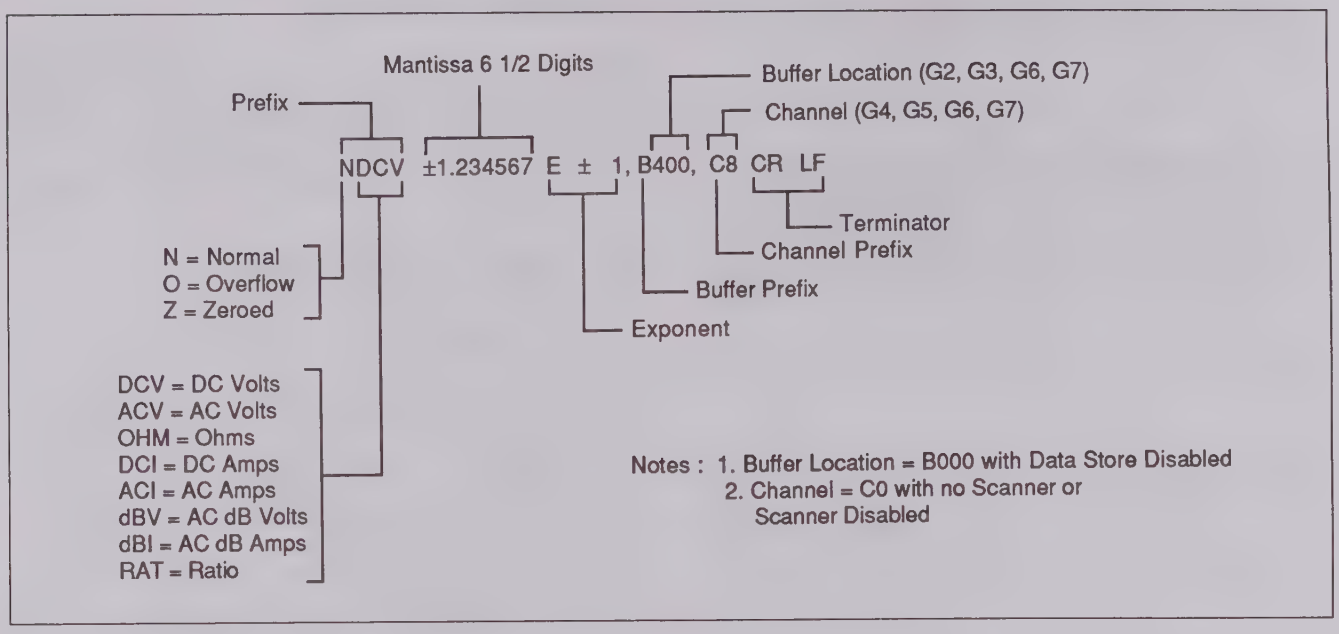

Mantissa 6 1/2 Digits
Prefix
Buffer Location (G2, G3, G6, G7)
Channel (G4, G5, G6, G7)
NDCV ±1.234567 E ± 1, B400, C8 CR LF
Terminator
Channel Prefix
Buffer Prefix
Exponent
N = Normal
O = Overflow
Z = Zeroed
DCV = DC Volts
ACV = AC Volts
OHM = Ohms
DCI = DC Amps
ACI = AC Amps
dBV = AC dB Volts
dBI = AC dB Amps
RAT = Ratio
Notes : 1. Buffer Location = B000 with Data Store Disabled
2. Channel = C0 with no Scanner or
Scanner Disabled

Figure 3-6. General Data Format

When the second statement is executed, the instrument will change to the G1 mode. The last two statements acquire data from the instrument and display the reading string on the CRT. Note that no prefix or suffix appears on the data string.

3.9.13 SRQ Mask (M) and Serial Poll Byte Format

The SRQ command controls which of a number of conditions within the Model 199 will cause the instrument to request service from the controller by asserting an SRQ. Once an SRQ is generated, that serial poll byte can be checked to determine if the Model 199 was the instrument that asserted the SRQ, and if so, what conditions can be checked by using the U1 command, as described in paragraph 3.9.13.

The Model 199 can be programmed to generate an SRQ under one or more of the following conditions:

1. When a reading is completed or an overrange condition occurs.
2. If a bus error occurs.
3. When the data store is full.
4. When the data store is ½ full.
5. If a trigger overrun error occurs.

Upon power up or after a DCL or SDC command is received, SRQ is disabled.

SRQ Mask—The Model 199 uses an internal mask to determine which conditions will cause an SRQ to be generated. Figure 3-7 shows the general format of this mask.

SRQ can be programmed by sending the ASCII letter "M" followed by a decimal number to set the appropriate bit in the SRQ mask. Decimal values for the various bits are summarized in Table 3-11. Note that the instrument may be programmed for more than one set of conditions simultaneously. To do so, simply add up the decimal bit values for the required SRQ conditions. For example, to enable SRQ under reading overflow and buffer full conditions, send M3X. To disable SRQ, send M0X. This command will clear all bits in the SRQ mask.

Serial Poll Byte Format—The serial poll byte contains information relating to data and error conditions within the instrument. The general format of the serial poll byte (which is obtained by using the serial polling sequence, as described in paragraph 3.8.8) is shown in Figure 3-7.

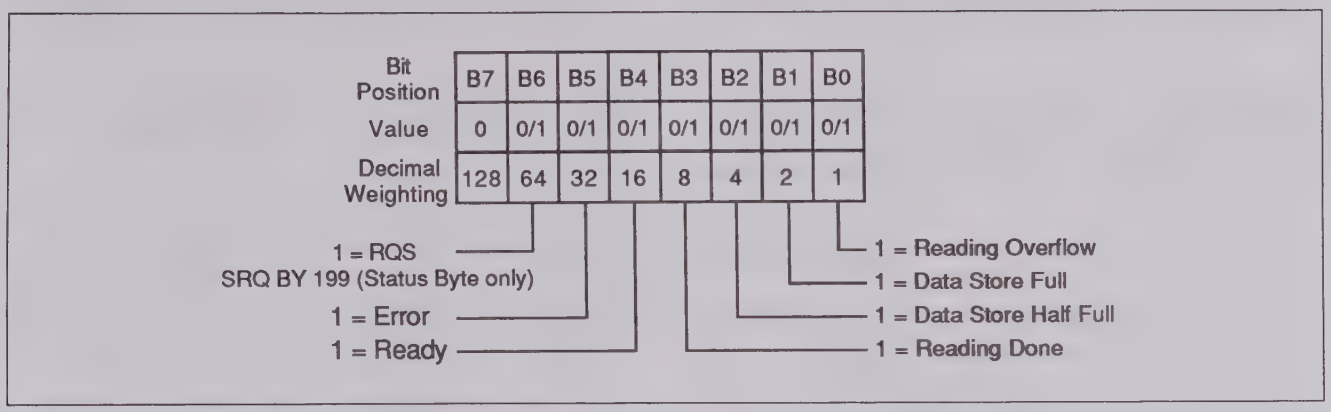

Bit Position
B7 B6 B5 B4 B3 B2 B1 B0
Value
0 0/1 0/1 0/1 0/1 0/1 0/1 0/1
Decimal Weighting
128 64 32 16 8 4 2 1
1 = RQS
SRQ BY 199 (Status Byte only)
1 = Error
1 = Ready
1 = Reading Overflow
1 = Data Store Full
1 = Data Store Half Full
1 = Reading Done

Figure 3-7. SRQ Mask and Serial Poll Byte Format

Table 3-11. SRQ Command Parameters

Command	Condition to Generate SRQ
M0	Disable
M1	Reading overflow
M2	Data store full
M4	Data store half full
M8	Reading done
M16	Ready
M32	Error

The bits in the serial poll byte have the following meanings:

Bit 0 (Reading Overflow)—Set when an overrange input is applied to the instrument. Cleared when the input is on range.

Bit 1 (Data Store)—Set when the defined data store size is full. Cleared by re-enabling data store.

Bit 2 (Data Store ½ Full)—Set when half the defined data store size is full. Cleared by re-enabling data store.

Bit 3 (Reading Done)—Set when the instrument has completed the present reading conversion. Cleared while processing a reading.

Bit 4 (Ready)—Set when the instrument has processed all previously received commands and is ready to accept additional commands over the bus. Cleared while the instrument is processing commands.

Bit 5 (Error)—Set when one of the following errors has occurred:

1. Trigger Overrun
2. Interval Overrun
3. Big String
4. Uncalibrated
5. Cal Locked
6. Conflict
7. No Remote
8. IDDC
9. IDDCO
10. Translator
11. No Scanner
12. Chan 4 Maximum
13. Channel 8 Maximum

The error bit is cleared by reading the U1 word.

The nature of the error can be determined with the U1 command as explained in paragraph 3.9.16. An explanation of each error can also be found in paragraph 3.9.16.

Bit 6 (RQS)—Provides a means to determine if an SRQ was asserted by the Model 199. If this bit is set, service was requested by the instrument.

Bit 7—Not used and always set to zero.

Note that the status byte should be read to clear the SRQ line once the instrument has generated an SRQ. All bits in the status byte will be latched when the SRQ is generated. Bit 6 (RQS) will be cleared when the status byte is read.

Programming Example—Enter the following program into the computer:

PROGRAM	COMMENTS
`10 REMOTE 726`	Set up for remote operation.
`15 CLEAR 726`	
`20 OUTPUT 726;''M32X''`	Program for SRQ on IDDCO.
`30 OUTPUT 726;''K5X''`	Attempt to program illegal option.
`40 S=SPOLL(726)`	Serial poll the instrument.
`45 IF NOT BIT(S,5) THEN 40`	Wait for SRQ error.
`50 PRINT ''B7 B6 B5 B4 B3 B2 B1 B0''`	Identify the bits.
`60 FOR I=7 TO 0 STEP -1`	Loop eight times.
`70 PRINT BIT (S,I);`	Display each bit position.
`80 NEXT I`	
`90 PRINT`	
`100 END`	

Once the program is entered and checked for errors, press the RUN key. The computer first places the instrument in remote (line 10) and then programs the SRQ mode of the instrument (line 20). Line 30 then attempts to program an illegal command option, at which point the instrument generates an SRQ and sets the bus error bit in its status byte. The computer then serial polls the instrument (line 40), and then displays the status byte bits in proper order on the CRT. In this example, the SRQ (B6) and error (B5) bits are set because of the attempt to program an illegal command option (K5). Other bits may also be set depending on instrument status.

3.9.14 EOI and Bus Hold-off Modes (K)

The K command allows control over whether or not the instrument sends the EOI command at the end of its data string, and whether or not bus activity is held off (through the NRFD line) until all commands sent to the instrument are internally processed once the instrument receives the X character. K command options include:

K0 = Send EOI with last byte; hold off bus until commands processed on X.
K1 = Do not send EOI with last byte; hold off bus until commands processed on X.
K2 = Send EOI with last byte; do not hold off bus on X.
K3 = Send no EOI with last byte; do not hold off bus on X.

Upon power up, or after the instrument receives a DCL or SDC command, the instrument will return to K0.

The EOI line on the IEEE-488 bus provides a method to positively identify the last byte in a multi-byte transfer sequence. Keep in mind that some controllers rely on EOI to terminate their input sequences. In this case, suppressing EOI with the K command may cause the controller input sequence to hang unless other terminator sequences are used.

The bus hold off mode allows the instrument to temporarily hold up bus operation when it receives the X character until it processes all commands sent in the command string. The purpose of the hold off is to ensure that the front end FETs and relays are properly configured before taking a reading. Keep in mind that all bus operation will cease--not just activity associated with the Model 199. The advantage of this mode is that no bus commands will be missed while the instrument is processing commands previously received.

The hold off period depends on the commands being processed. Table 3-12 lists hold off times for a number of different commands. Since a NRFD hold off is employed, the handshake sequence for the X character is complete.

NOTE

With K0 or K1 asserted, hold-off will also occur on an EOI and a terminator. These delays allow for proper operation of the Translator software, since "X" cannot be used in Translator words.

Programming Example—To program the instrument for the K2 mode, enter the following statements into the computer:

```
REMOTE 726
OUTPUT 726; ''K2X''
```

When the second statement is executed, the instrument will be placed in the K2 mode. In this mode, EOI will still be transmitted at the end of the data string, but the bus hold-off mode will be disabled.

Table 3-12. Bus Hold-off Times (Typical)

Command	Typical Hold Off Time
A0→A1	176msec
F0→F1	105msec
F5→F6	160msec
B0→B1	49msec
G0→G1	58msec
J0→J1	1.15msec
K0→K1	57msec
M0→M1	57msec
N0→N1	105msec
DN99→Dx	55msec
O0→O1	104msec
Q10→Q20	106msec
R0→R1	106msec
R2→R3	105msec
S0→S1	158msec
T0→T1	102msec
W20→W40	107msec
Y0→Y1	58msec
Z0→Z1	105msec
I20→I30	112msec
L0→L1	100msec
C0→C1	8.85sec (DCV) 18sec (20MΩ)
P0→P1	106msec

Note: Hold-off occurs on X or <CR><LF> when enabled.

3.9.15 Terminator (Y)

The terminator sequence that marks the end of the instrument's data string or status word can be programmed by sending the Y command followed by an appropriate number. The default terminator sequence is the commonly used carriage return, line feed (CR LF) sequence (Y0). The terminator will assume this default value upon power up, or after the instrument receives a DCL or SDC command. Programmable terminators include:

Y0 = CR LF
Y1 = LF CR
Y2 = CR
Y3 = LF

HP-85 Programming Example—To reserve the default (CR LF) terminator sequence, type the following lines into the computer.

```
REMOTE 726
OUTPUT 726;"Y0X"
```

When the second statement is executed, the normal terminator sequence will be reserved; the instrument will terminate each data string or status word with a (CR LF).

3.9.16 Status (U)

The status command allows access to information concerning various operating modes and conditions of the Model 199. Status commands include:

U0 = Send machine status word.
U1 = Send error conditions.
U2 = List Translator words.
U3 = Send a value indicating the buffer size.
U4 = Send the present value (V).
U5 = Send input switch status (front/rear).

When the command sequence U0X is transmitted, the instrument will transmit the status word instead of its normal data string the next time it is addressed to talk. The status word will be transmitted only once each time the U0 command is given. To make sure that correct status is transmitted, the status word should be requested as soon as possible after the command is transmitted.

The format of U0 status is shown in Figure 3-8. Note that the letters correspond to modes programmed by the respective device-dependent commands. The default values in the status word are also shown in Figure 3-8. Note that all returned values correspond to the programmed numeric values. For example, if the instrument is presently in the R3 range, the second (R) byte in the status word will correspond to an ASCII 3.

The U1 command allows access to Model 199 error conditions in a similar manner. Once the sequence U1X is sent, the instrument will transmit the error conditions with the format shown in Figure 3-9 the next time it is addressed to talk in the normal manner. The error condition word will be sent only once each time the U1 command is transmitted. Note that the error condition word is actually a string of ASCII characters representing binary bit positions. An error condition is also flagged in the serial poll byte, and the instrument can be programmed to generate an SRQ when an error condition occurs. See paragraph 3.9.13. Note that all bits in the error condition word and the serial poll byte error bit will be cleared when the word is read. In addition, SRQ operation will be restored after an error condition by reading U1.

FACTORY DEFAULT																		
199	1	0	0	0	0	0	00	0	0	000000	4	1	6	000000	0	0	0	0/1
199	A	B	F	G	J	K	NN	0	P	QQQQQQ	R	S	T	WWWWWW	Y	Z	CAL SW	SCANNER

MODEL NUMBER PREFIX (199)

AUTO/CAL MULTIPLEX (A)
0=DISABLED
1=ENABLED

READING MODE (B)
0=A/D CONVERTER
1=DATA STORE SINGLE READING
2=DATA STORE DUMP

FUNCTION (F)
0=DC VOLTS
1=AC VOLTS
2=OHMS
3=DC CURRENT
4=AC CURRENT
5=ACV dB
6=ACA dB

DATA FORMAT (G)
0=RDG WITH PREFIX
1=RDG WITHOUT PREFIX
2=RDG WITH PREFIXES AND BUFFER LOCATION
3=RDG WITHOUT PREFIX AND WITH BUFFER LOCATION
4=RDG WITH PREFIXES AND CHANNEL
5=RDG WITHOUT PREFIXES AND WITH CHANNEL
6=RDG WITH PREFIX, BUFFER LOCATION, AND CHANNEL
7=RDG WITHOUT PREFIX, WITH BUFFER LOCATION AND CHANNEL

SELF-TEST (J)
0=INACTIVE
1=ROM, RAM and E²PROM PASSED
2=E²PROM FAILED

EOI; BUS HOLD-OFF (K)
0=EOI AND HOLD-OFF
1=NO EOI AND HOLD-OFF
2=EOI AND NO HOLD-OFF
3=NO EOI AND NO HOLD-OFF

SRQ (M)
M00=DISABLED
M01=READING OVERFLOW
M02=DATA STORE FULL
M04=DATA STORE HALF FULL
M08=READING DONE
M16=READY
M32=ERROR

SCANNER (N)
N0=CHANNELS OPEN
N1-N8=CHANNEL CLOSED
N10=STEP, OPEN
N11-N18=STEP, LIMIT
N20=SCAN, OPEN
N21-N28=SCAN, LIMIT

POLE/RATIO
0=2-POLE
1=4-POLE
2=2-POLE RATIO
3=4-POLE RATIO

FILTER (P)
0=FILTER DISABLED
1=INTERNAL FILTER ENABLED
2=INTERNAL AND FRONT PANEL FILTER ENABLED

READING INTERVAL (Q)
nnnnnn=INTERVAL (15msec to 999999msec)

RANGE (R)

	DCV	ACV	DCA	ACA	OHMS	ACV dB	ACA dB
0	Auto	Auto	Auto	Auto	Auto	Auto	Auto
1	300mV	300mV	30mA	30mA	300 Ω	Auto	Auto
2	3 V	3 V	3 A	3 A	3 kΩ	Auto	Auto
3	30 V	30 V	3 A	3 A	30 kΩ	Auto	Auto
4	300 V	300 V	3 A	3 A	300 kΩ	Auto	Auto
5	300 V	300 V	3 A	3 A	3MΩ	Auto	Auto
6	300 V	300 V	3 A	3 A	30MΩ	Auto	Auto
7	300 V	300 V	3 A	3 A	300MΩ	Auto	Auto

RATE (S)
0=4½ DIGITS
1=5½ DIGITS
Integration Period: 4½d=2.59msec, 5½d=Line cycle

TRIGGER (T)
0=CONTINUOUS ON TALK
1=ONE-SHOT ON TALK
2=CONTINUOUS ON GET
3=ONE-SHOT ON GET
4=CONTINUOUS ON X
5=ONE-SHOT ON X
6=CONTINUOUS ON EXTERNAL TRIGGER
7=ONE-SHOT ON EXTERNAL TRIGGER

TRIGGER DELAY (W)
nnnnn=00000msec to 999999msec

TERMINATOR (Y)
0=CR LF
1=LF CR
2=CR
3=LF

ZERO (Z)
0=DISABLED
1=ENABLED

CALIBRATION SWITCH
0=DISABLED
1=ENABLED

SCANNER PRESENT
0=NOT INSTALLED
1=INSTALLED

Figure 3-8. U0 Machine Status Word and Default Values

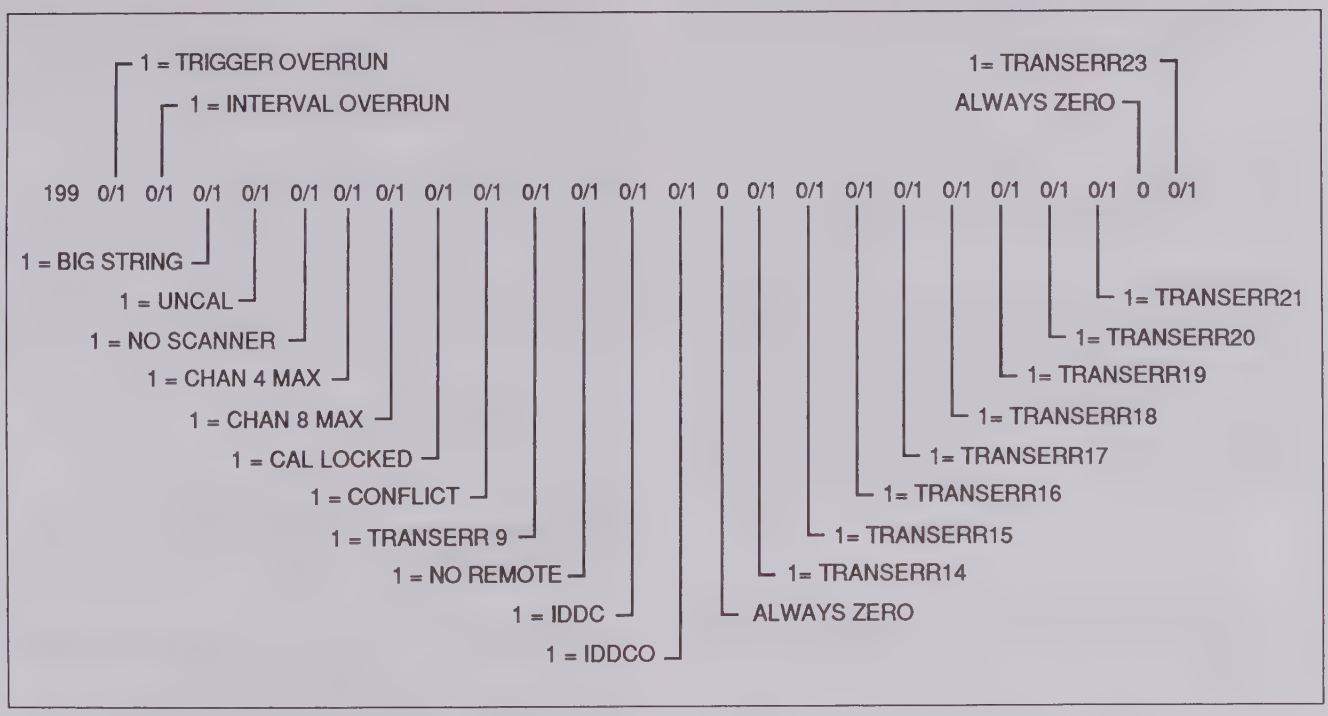


Figure 3-9. U1 Error Status Word

The various bits in the error condition word are described as follows:

TRIGGER OVERRUN—Set when the instrument receives a trigger while it is still processing a reading from a previous trigger.

INTERVAL OVERRUN—Set when the instrument cannot run as fast as the selected interval.

BIG STRING—Set if more than a 10 character message is sent using the display (D) command.

UNCAL—Set when E²PROM memory fails the self test. Instrument calibration is invalid.

NO SCANNER—Set if a scanner command is sent with no scanner installed.

CHAN 4 MAX—Set if attempting to program channels 5 through 8 in the 4-pole mode.

CHAN 8 MAX—Set if scanner commands N9 or N19 are sent.

CAL LOCKED—Set when trying to calibrate the instrument with the calibration switch in the disable position.

CONFLICT—Set when trying to calibrate the instrument while it is in an improper state. (i.e. dB function).

Translator Error (TRANSERR)—Set when any one of ten possible Translator errors occur. Table 3-15 in paragraph 3.10 lists and describes the Translator errors.

NO REMOTE—Set when a progamming command is received when REN is false.

IDDC—Set when an illegal device-dependent command (IDDC), such as E1X is received ("E" is illegal).

IDDCO—Set when an illegal device-dependent command option (IDDCO) such as T9X is received ("9" is illegal).

NOTE
The complete command string will be ignored if an IDDC, IDDCO or no remote error occurs.

The U2 command lists the Translator words that have been defined by the operator. The list will be transmitted only once each time the command is received.

The U3 command allows the user to find out the current defined size of the buffer. The buffer size is controlled by the I command. When this command is transmitted, the instrument will transmit the value the next time it is addressed to talk. This information will be transmitted only once each time the command is received. The U3 value will not be cleared when read; thus, the U3 value is always current. For example:

SZ = 010

The U4 command sends the present value. The value is a calibration value or zero value, as programmed by the V command.

The U5 command sends a value that defines the status of the input switch. A value of 0 indicates that the front panel input terminals are selected, while a value of 1 indicates that the rear panel input terminals are selected. For example:

RF = 1

Progamming Example—Enter the following statements into the computer to obtain and display the machine status word (U0).

PROGRAM	COMMENTS
`10 REMOTE 726`	Send remote enable.
`20 DIM A$[40]`	
`30 OUTPUT 726;''U0X''`	Send U0 command.
`40 PRINT ''mdlABFGJKMMN NOPQQQQQQRSTWWWWWW YZ*''`	
`50 ENTER 726;A$`	Obtain U0 status from instrument.
`60 PRINT A$`	Display U0 status word.
`70 ENTER 726;A$`	Get normal reading.
`80 PRINT A$`	Display normal reading.
`90 END`	

After entering the program, run it by pressing the RUN key. The machine conditions of the Model 199 will be listed on the CRT display. To show that status is transmitted only once, a normal reading is requested and displayed last.

3.9.17 Auto/Cal Multiplex (A)

The Model 199 has built-in multiplex routines that automatically calibrate and zero the instrument, so as to maintain its high accuracy. The multiplex routines can be controlled through commands below. See paragraph 2.7.2 for more information.

A0 = Disable multiplex
A1 = Enable multiplex

Upon power up or after a DCL or SDC command, the instrument will return to the default condition.

Programming Example—Disable multiplex by entering the following statements into the computer:

```
REMOTE 726
OUTPUT 726;''A0X''
```

When the second statement is executed, the multiplexer routines will be disabled.

3.9.18 Trigger Delay (W)

The delay command controls the time interval that occurs from the point the instrument is triggered until it begins integration of the input signal. This feature is useful in situations where a specific time period must transpire to allow an input signal to settle before measurement. During the delay period, the input multiplexing FETs are switched on so the instrument is set to begin integration upon conclusion of the programmed delay period. A delay period can be programmed using the following command:

Wn

Here, n represents the delay value in milliseconds. The range of programmable delay values is from 0msec to 999999msec.

Examples:

For a delay of 0.002sec send W2X.
For a delay of 30.05sec send W30050X.
For a delay of 60sec send W60000X.

Upon power up or after receiving a DCL or SDC command, the instrument will return to the default condition.

Programming Example—To program a 250msec delay period into the instrument, enter the following statements into the computer:

```
REMOTE 726
OUTPUT 726;''W250X''
```

The instrument will wait for 250msec after each triggered conversion before executing the next conversion period.

3.9.19 Self-Test (J)

The J command causes the instrument to perform tests it automatically performs upon power up. When the self-test command is given, the Model 199 performs the following tests:

1. ROM Test
2. RAM Test
3. E²PROM Test

J command parameters include:

J0 = Perform self-test.

If the self-test is successful, the J byte in the U0 status word will be set to 1. If E²PROM fails, the message "UNCAL" will be displayed and the J byte in the U1 status word will be set to 2. An E²PROM failure is also flagged in the U1 status word. If ROM and RAM fails, the instrument will lock up.

See paragraph 6.7.2 for more information on these tests and recommendations to resolve a failure.

Programming Example—Enter the following statements into the computer to perform the Model 199 self-test:

```
REMOTE 726
OUTPUT 726;''J0X''
```

When the END LINE key is pressed the second time, the instrument performs the self-test. If successful, the self-test byte (J) in the U0 status word will be set to 1.

3.9.20 Hit Button (H)

The hit button command allows the user to emulate virtually any front panel control sequence. The H command is sent by sending the ASCII letter followed by a number representing a front panel control. These control numbers are shown below.

Command	Button
H0	VOLTS
H1	OHMS
H2	AMPS
H3	AC
H4	ZERO
H5	AUTO
H6	▼
H7	▲
H8	SCANNER
H9	TRIGGER
H10	SHIFT

Examples:

H0X—Selects the VOLTS function.
H2X—Selects the AMPS function.

Programming Example—Enter the following statements into the computer to place the instrument in the ohms function:

```
REMOTE 726
OUTPUT 726;''H1X''
```

The instrument is placed in the ohms function.

3.9.21 Display (D)

The display command controls the ASCII messages that can be placed onto the Model 199 display. Messages are controlled with the following commands:

Da = Display character "a", where "a" represents a printable ASCII character. Up to 10 characters may be sent.
D = Restores display back to normal.

Notes:
1. In order to have spaces preceding the beginning of the message and between message words, use the @ symbol to represent each space. For example, to display the message "Model 199" starting at the second display character (one space), send the following command string:

```
''D@MODEL@199X''
```

2. Spaces in a command string are ignored.
3. Sending a message that exceeds 10 characters will result in the BIG STRING error message being displayed.

Programming Example—Enter the following statements into the computer to display the message "MODEL 199":

```
REMOTE 726
OUTPUT 726;''D@MODEL@199X''
```

The instrument model number will be displayed. Display operation may be returned to normal by entering the following statement:

```
OUTPUT 726;''DX''
```

3.10 TRANSLATOR SOFTWARE

The built in Translator software allows the user to define his own words in place of Keithley's defined device-dependent commands. One word can replace a single command or a string of commands. For example, the word ACV can be sent in place of F1, and the word SETUP1 can be sent in place of F3R1T2S0Z1U0M2. Also, Keithley commands can be translated to emulate functions of other units. For example, the word RA, which is used by H-P to select autorange, can be sent in place of R0. There are certain words and characters that cannot be used as defined Translator words. These reserved words and character make up the Translator software syntax and are listed in Table 3-13.

Table 3-13. Translator Reserved Words and Character

Word/Character	Description
ALIAS	Used at the beginning of a command string to define Translator words.
;	Used to terminate the Translator string (one space must precede it).
$	Used to define wild card Translator words. Values sent with a wild card Translator word select options of the equivalent DDC.
NEW	Tells the Model 199 to recognize Translator words.
OLD	Tells the Model 199 to only recognize the Keithley device-dependent commands.
SAVE	Saves Translator words as power up default.
LIST	Used to list the Translator words.
FORGET	Used to purge Translator words from memory.

3.10.1 Translator Format

The basic format for defining a Translator word is shown in the following example command string, which defines the word SETUP1 as a substitute for F1R0X.

"ALIAS SETUP1 F1R0X ;"

Where:

ALIAS is a reserved word that precedes the Translator word.

SETUP1 is the desired Translator word.

F1R0X is the Keithley command string.

; is a reserved character necessary to terminate the Translator string.

(spaces) must be used to separate words and the ";" character.

When SETUP1 is sent over the IEEE-488 bus, the instrument will go to the ACV function (F1) and enable autorange (R0).

Translator words that contain conflicting device-dependent commands, such as F1 and F2, can be defined. When sending the command word over the bus, the device-dependent command that was last entered will prevail. For example, sending a Translator word in place of F0F1X will place the instrument in the F1 function.

NOTES:

1. Trying to define a Translator word that already exists will cause an error message to be displayed briefly. That Translator word will retain its original definition.
2. A Translator word cannot exceed 31 characters.
3. The Translator buffer can hold approximately 100 18-character Translator words.
4. The character X and $ cannot be used in Translator words.
5. The Model 199 will not recognize an undefined Translator word sent over the bus.
6. A valid Translator word sent over the bus while the instrument is in the OLD mode will not be recognized. However, the instrument will try to execute (on the next X) the letters and numbers of the word as if they were device-dependent commands. To avoid this problem, it is recommended that NEW be sent before trying to execute Translator words. See paragraph 3.10.3 for an explanation of NEW and OLD.
7. Translator error messages are listed and described in Table 3-14.
8. Translator error numbers correspond to the U1 error word bit positions; see Figure 3-9.
9. A <CR> <LF> sequence must terminate any translator execution string for proper execution. Most controllers do add the necessary terminator automatically, but some may not.

Programming Example—Enter the following program into the computer to define a Translator word (SETUP1) to emulate the command string F1R0X:

```
REMOTE 726
OUTPUT 726;''ALIAS SETUP1 F1R0X ;''
OUTPUT 726;''SETUP1''
```

The Translator word will be defined to emulate the Keithley command string. The instrument will go to the ACV function (F1) and enable autorange (R0).

Table 3-14. Translator Error Messages

Display Message	Explanation	Example Error String
TRANSERR 9	No more memory left for Translator words.	—
TRANSERR14	Use of more than one ALIAS in a definition.	"ALIAS TEST1 F1X ALIAS TEST2 R1X ;"
TRANSERR15	Translator word exceeds 31 characters.	"ALIAS ITHINKTHISISTHIRTYTWOCHARACTERS! F1X ;"
TRANSERR16	Use of an X in a Translator word.	"ALIAS XRAY F1X ;"
TRANSERR17	Trying to define a Translator word that already exists. The second string in the example is the error string.	"ALIAS SETUP F1X ;" "ALIAS SETUP R1X ;"
TRANSERR18	Use of a $ in a Translator word.	"ALIAS $200 F1X ;"
TRANSERR19	Sending the ; character.	";"
TRANSERR20	Use of LIST in a Translator definition.	"ALIAS DOG F1X LIST ;"
TRANSERR21	Use of FORGET in a Translator definition.	"ALIAS DOG F1X FORGET ;"
TRANSERR23	Use of SAVE in a Translator definition.	"ALIAS DOG F1X SAVE ;"

3.10.2 Wild Card ($)

An advanced feature of Translator software is its wild card capabilities. By using the reserved character "$", the same basic Translator word can be used to select all options of a command. With this feature, a DDC option number is sent with the wild card Translator word. The format for using the wild card is shown in the following example, which defines the word FUNCTION as a substitute for the F command:

```
"ALIAS FUNCTION F$X ;"
    "FUNCTION 1"
    "FUNCTION 2"
```

The first statement defines FUNCTION as the wild card Translator word for the F command. The wild card ($) will allow any valid option number of the F command (0 through 6) to be sent with the word. The second statement which is the substitute for the F1 command, will place the instrument in the ACV function. The third statement is a substitute for the F2 command, and will place the instrument in the ohms function.

NOTES:

1. When sending a wild card Translator word over the bus, there must be a space between the Translator word and the option number.
2. If a wild card Translator word is sent without an option number, the instrument will default to option 0.

Programming Example—Enter the following program to define a wild card Translator word to emulate the P (filter) command.

```
REMOTE 726
OUTPUT 726; ''ALIAS FILTER P$X ;''
OUTPUT 726; ''FILTER 2''
```

The second statement defines FILTER as the wild card Translator word for the P command. The third statement enables the front panel filter (FLTR on).

3.10.3 NEW and OLD

NEW is a reserved word that tells the instrument that the ensuing commands may be defined Translator words. The instrument will then respond to the Translator words as well as Keithley device-dependent commands. The reserved word ALIAS automatically places the instrument in the NEW mode. NEW is also used to combine Translator words and is explained in paragraph 3.10.4.

OLD is a reserved word that prevents the instrument from responding to the defined Translator words. In this mode, only the Keithley device-dependent commands will be recognized over the bus.

Programming Example—Enter the following statements into the computer to place the instrument in the NEW mode:

```
REMOTE 726
OUTPUT 726;''NEW''
```

The instrument will go into the NEW mode.

3.10.4 Combining Translator Words

Existing Translator words can be combined resulting in a Translator word that contains the commands of the two (or more) combined words. For example, existing Translator words SETUP1 and SETUP2 can be combined and named SETUP3. When SETUP3 is sent over the bus, the commands of both SETUP1 and SETUP2 will be executed. The format for combining Translator words is shown in the following example:

"ALIAS SETUP3 NEW SETUP1 NEW SETUP2 ;"

Where:

SETUP3 is the new Translator word.

SETUP1 and SETUP2 are words to be combined.

NEW is a reserved word that tells the instrument that SETUP1 and SETUP2 are Translator words and not Keithley device-dependent commands.

Even though the two words were combined to form SETUP3, SETUP1 and SETUP2 still exist as valid Translator words.

Wild card Translator words can also be combined with other Translator words. The option number used with the new word will apply only to the first wild card word in the string. For example, assume that FILTER (emulating the P command) and FUNCTION (emulating the F command) are wild card Translator words that are to be combined with the normal Translator word SETUP1. The format might look like this:

"ALIAS TEST NEW SETUP1 NEW FUNCTION
NEW FILTER ;"

The new Translator word is TEST. Whenever TEST is sent, the option value sent with that word will only affect function since FUNCTION is the first wild card command in the string. For example, TEST might be sent over the bus in the following format:

"TEST 3"

The "3" in the command string will ony affect the FUNCTION command. In this example the instrument will be placed in the DCA function (F3). Since the FILTER command does not have an assigned option value (due to its position in the string), it will default to 0 (disable).

Programming Example—The following sequence will create two Translator words and then combine them to form a third Translator word:

```
REMOTE 726
OUTPUT 726;''ALIAS SETUP1 F1X ;''
OUTPUT 726;''ALIAS SETUP2 R0X ;''
OUTPUT 726;''ALIAS SETUP3 NEW SETUP1 NEW
SETUP2 ;''
```

The second and third program statements define the two Translator words. The two words combine to form the new word (SETUP3).

3.10.5 Combining Translator Words With Keithley IEEE-488 Commands

One or more existing Translator words (including wild card words) can be combined with Keithley IEEE commands resulting in a Translator word that contains the commands of the Translator words and the Keithley IEEE commands. The format for combining Translator words with Keithley IEEE commands is shown in the following example:

"ALIAS SETUP3 NEW SETUP1 NEW SETUP2 P1Z1X ;"

Where:
SETUP3 is the new Translator word.
SETUP1 and SETUP2 are the existing words.
P1Z1X is the Keithley IEEE command string.
NEW tells the instrument that SETUP1 and SETUP2 are Translator words.

When the Translator word SETUP3 is asserted over the bus, the commands of the two Translator words and the Keithley IEEE command string will be executed.

Programming Example—The following sequence will create two Translator words and then combine them with a Keithley IEEE command string to form a new Translator word:

```
REMOTE 726
OUTPUT 726;''ALIAS SETUP1 F1X ;''
OUTPUT 726;''ALIAS SETUP2 R0X ;''
OUTPUT 726;''ALIAS SETUP3 NEW SETUP1
    NEW SETUP2 P1Z1X ;''
```

The second and third statements create two Translator words. The two Translator words are combined to form the word SETUP3.

3.10.6 Executing Translator Words and Keithley IEEE Commands

Translator words (including wild card words) and Keithley IEEE commands can be executed in the same command string. The format for doing this is demonstrated in the following examples:

"SETUP1 P1Z1X"
"FUNCTION 2 P1Z1X"

When the first command string is sent over the bus, the commands in SETUP1 and the Keithley IEEE commands will be executed. When the second string is sent, the second option of the wild card FUNCTION command and the Keithley IEEE commands will be executed.

Programming Example—The following program will assert the commands of an existing Translator word and the standard Keithley IEEE commands over the bus:

```
REMOTE 726
OUTPUT 726;''SETUP1 P1Z1X''
```

The commands of SETUP1 and the Keithley IEEE commands (P1Z1X) will be sent over the bus.

3.10.7 SAVE

Translator words can be remembered by the instrument as power up default words by sending the reserved word SAVE. If SAVE is not sent, Translator words will be lost when the instrument is turned off, Reset is run, or an SDC, DCL or L0 is sent over the bus.

When SAVE is sent, the instrument also remembers if it was in NEW or OLD. If the instrument is in NEW when SAVE is sent, it will power up in NEW. If the instrument is in OLD when SAVE is sent, it will power up in OLD.

Programming Example—With one or more Translator words already defined, enter the following statements into the computer to retain them as power up default words:

```
REMOTE 726
OUTPUT 726;''SAVE''
```

Current Translator words will become power up default words.

3.10.8 LIST

LIST is a reserved word that can be used to list the existing Translator words stored in temporary memory. The most recent defined word will be listed first.

NOTES:

1. The U2 command can also be used to list the Translator words (see paragraph 3.9.16).
2. If there are no Translator words in memory, nothing will be displayed when the list is requested.

Programming Example—With Translator words already defined, enter he following program statements to list them:

```
10 REMOTE 726
20 OUTPUT 726;''LIST''
30 ENTER 726; A$
40 PRINT A$
50 END
```

The second and third statements will send the word list to the computer. The Translator words will be displayed.

3.10.9 FORGET

FORGET is a reserved word that is used to purge all Translator words from temporary memory. However, Translator words that were saved in E²PROM by the SAVE command will again be available after power to the instrument is cycled, Reset is RUN, or DCL, SDC or L0 is sent over the bus.

To purge Translator words from E²PROM, first send the FORGET command and then send the SAVE command.

Programming Example—Enter the following statements into the computer to purge all Translator words from temporary memory:

```
REMOTE 726
OUTPUT 726;''FORGET''
```

3.11 BUS DATA TRANSMISSION TIMES

A primary consideration is the length of time it takes to obtain a reading once the instrument is triggered to make a conversion. The length of time will vary somewhat depending on the selected function and trigger mode. Table 3-15 gives typical times.

3.12 SCANNER PROGRAMMING

The paragraphs below discuss the programming commands necessary to control the optional Model 1992 2/4 Pole Scanner. The Model 1992 allows you to individually switch or scan up to eight 2-pole channels or four 4-pole channels.

Commands to control the scanner are summarized in Table 3-16. For detailed information on scanner connections, refer to paragraph 2.11.

Table 3-15. Typical Trigger to First Byte Out Times

Range	AOSO	AISO	AOSI	AISI
			DCV	
300 V	8msec	15.9msec	25msec (27.8msec)	103msec (113msec)
30 V	8msec	15.9msec	25msec (27.8msec)	107msec (119msec)
3 V	8msec	15.9msec	25msec (27.8msec)	106msec (119msec)
300mV	8msec	15.9msec	25msec (28 msec)	108msec (122msec)
			ACV	
300 V	8msec	15msec	24.1msec (28msec)	30.9msec (34.1msec)
30 V	8msec	15msec	25 msec (28msec)	29.9msec (34.1msec)
3 V	8msec	15msec	25 msec (28msec)	31.1msec (34.1msec)
300mV	8msec	15msec	25 msec (28msec)	30.9msec (34.1msec)
			ACA	
30mA	7.7msec	15.1msec	25.3msec (27.1msec)	30.9msec (34.1msec)
3 A	7.9msec	15.1msec	24.9msec (26.9msec	30.9msec (34.1msec)
			DCA	
30mA	7.9msec	14.9msec	25.1msec (28.1msec)	30.9msec (34.7msec)
3 A	7.9msec	14.9msec	25.1msec (27.9msec)	30.9msec (34.1msec)
			OHMS	
300	30.1msec	50 msec	59.2msec (66.2msec)	97 msec (113 msec)
3 k	21.9msec	50 msec	58.8msec (64.9msec)	96.2msec (109.8msec
30 k	21.9msec	50 msec	58.8msec (65.8msec)	96.2msec (111.4msec)
300 k	—	—	59.2msec (62.5msec)	97.8msec (109.8msec)
3M	—	—	58.1msec (63.7msec)	112.2msec (125 msec)
30M	—	—	27.8msec (31.8msec)	353.5msec (362.5msec)
300M	—	—	27.8msec (30.9msec)	353.5msec (362.5msec)

( ) = 50Hz operation
Internal filter off
T1 mode

A0 = mux off
A1 = mux on

S0 = 4½
S1 = 5½

Table 3-16. Scanner Programming Commands

Mode	Command	Description		Paragraph
Scanner Setup	N0	All channels open		3.12.1
		2-pole	4-pole	
	N1	1	1	
	N2	2	2	
	N3	3	3	
	N4	4	4	
	N5	5	CHAN 4 MAX ERROR	
	N6	6	CHAN 4 MAX ERROR	
	N7	7	CHAN 4 MAX ERROR	
	N8	8	CHAN 4 MAX ERROR	
	N9	Step mode		
	N10	Stop scan, all channels open		
		2-Pole Limit	4-Pole Limit	
	N11	1	1	
	N12	2	2	
	N13	3	3	
	N14	4	4	
	N15	5	CHAN 4 MAX ERROR	
	N16	6	CHAN 4 MAX ERROR	
	N17	7	CHAN 4 MAX ERROR	
	N18	8	CHAN 4 MAX ERROR	
	N19	CHAN 8 MAX ERROR	CHAN 4 MAX ERROR	
	N20	Stop scan, all channels open		
		2-Pole Limit	4-Pole Limit	
	N21	1	1	
	N22	2	2	
	N23	3	3	
	N24	4	4	
	N25	5	CHAN 4 MAX ERROR	
	N26	6	CHAN 4 MAX ERROR	
	N27	7	CHAN 4 MAX ERROR	
	N28	8	CHAN 4 MAX ERROR	
Pole/Ratio	O0	2-pole		3.12.2
	O1	4-pole		
	O2	2-pole ratio		
	O3	4-pole ratio		
Scan Interval	Q0	Default 175msec interval (SELECT OFF)		3.12.3
	Qn	n=interval in msec (15 ≤ 999999msec)		
Trigger Delay*	Wn	n=delay in msec (0 ≤ 999999msec)		3.12.4

*Delay to be used as channel settling time.

3.12.1 Scanner Setup (N)

The scanner setup command allows you to control channels individually, scan one channel per trigger or interval, or scan one set of channels per trigger or interval, as discussed below.

Manual Channel Control

The commands below open all channels or close each individual channel by sending the appropriate command.

N0 All channels open.

For the following commands, the indicated channel will be closed. The closed channel number will appear in the right most digit of the display.

	Closed Channel: 2-Pole	4-Pole
N1	1	1
N2	2	2
N3	3	3
N4	4	4
N5	5	CHAN 4 MAX Error
N6	6	CHAN 4 MAX Error
N7	7	CHAN 4 MAX Error
N8	8	CHAN 4 MAX Error
N9	CHAN 8 MAX Error	CHAN 4 MAX Error

Step (N10-N18)

In the step mode, the instrument scans one channel per interval (continuous trigger mode), or one channel per trigger (one-shot trigger mode). With each interval or trigger, the instrument closes a channel, takes a reading, and then opens that channel. Subsequent intervals or triggers advance channels to repeat the sequence.

The number of channels per step sequence is determined by the command option used, which also sets the channel limit. The reading interval is set by the Q command discussed in paragraph 3.12.3. Available triggers include front panel, external trigger input (rear panel), and IEEE-488 talk, GET, and X commands. The trigger source is determined by the T command.

N10 Open all channels and stop step sequence. Subsequent intervals or triggers will not cause stepping.

For the following, the closed channel number appears in the right-most digit of the display.

	2-pole Limit	4-pole Limit
N11	1	1
N12	2	2
N13	3	3
N14	4	4
N15	5	CHAN 4 MAX Error
N16	6	CHAN 4 MAX Error
N17	7	CHAN 4 MAX Error
N18	8	CHAN 4 MAX Error
N19	CHAN 8 MAX Error	CHAN 4 MAX Error

Scan Mode

The scan mode commands allow you to scan a complete set of channels per programmed interval (continuous trigger mode) or trigger (one-shot mode), with the channel limit determined by the command option. For example, if a limit of four is set, the unit will begin at channel 1 and then scan through channels 2 to 4 with each trigger stimulus or interval.

N20 Open all channels and terminate scan sequence.

For the following, the closed channel number will appear in the right-most digit of the display.

	2-pole Limit	4-pole Limit
N21	1	1
N22	2	2
N23	3	3
N24	4	4
N25	5	CHAN 4 MAX Error
N26	6	CHAN 4 MAX Error
N27	7	CHAN 4 MAX Error
N28	8	CHAN 4 MAX Error

Power-up DCL/SDC Default

Upon power up, or after a DCL or SDC, the N0 mode (all channels open) will be selected.

NOTES:

1. In order to use all eight channels in the 2-pole mode, the A and B outputs must be connected in parallel with the DMM inputs, as discussed in paragraph 2.11.
2. When using the scanner with data store, the number of sets of data that are stored is determined both by the data store size (I) command, as well as the number of channels per scan. For example, with a programmed size of 400 readings, and a scan limit of eight channels, 50 sets of data will be stored (400/8=50).
3. A "CHAN 4 MAX" error will occur if you attempt to program a limit greater than 4 with the unit in the 4-pole mode.
4. Sending a scanner command with no scanner installed will result in an "IDDC" error.

Programming Example—To demonstrate scanner programming, close channel 3 by entering the following statements.

```
REMOTE 726
OUTPUT 726 ;''N3X''
```

Note that the closed channel (3) is displayed in the rightmost digit.

To open the channel and return the display to normal, enter the following statement.

```
OUTPUT 726 ;''N0X''
```

3.12.2 Pole/Ratio Mode (O)

The O command controls 2/4 pole normal mode operation, as well as 2/4 pole ratio operation. In the 2-pole mode, up to eight channels can be scanned, while a maximum of four channels can be scanned in the 4-pole mode.

NOTE

If you attempt to program the 4-pole mode with channels 5-8 already closed, the pole mode will not be changed and a "CHAN 4 MAX" error will occur. The closed channel will not be opened.

In the ratio mode, the unit computes the ratio between the channel 2 through 8 reading to the channel 1 reading. in order to determine ratio, the unit first takes a reading on channel 1, and then computes the ratio for the remaining channels as follows:

$$R = \frac{CHn}{CH1}$$

Where: R = ratio
CHn = channel number (2 through 8)
CH1 = channel 1

The result is then sent over the bus as requested or stored in the data store buffer if enabled. Ratio values are identified with the RAT prefix in the data string, which is discussed more fully in paragraph 3.9.12.

Upon power up, or after a DCL or SDC, the O0 (2-pole) mode will be in effect.

Programming Example—Enter the statements below to program the unit to operate in the 4-pole mode.

```
REMOTE 726
OUTPUT 726 ;''O1X''
```

3.12.3 Reading Interval and Delay Programming

The programmed reading interval determines the time period between channels in the step mode, and the time period between sets of channels in the scan mode. Interval is programmed with the Q command as follows:

Q0 = Default interval, 175msec (SELECT ON)
Qn = User programmed interval

Here, n is the interval time in milliseconds, with an allowable range of 15 to 999 999msec. The factory default value for interval is 175msec. The instrument will assume that value upon power up, or after a DCL or SDC.

A channel settling time can be programmed by using the delay (W) command. When a scan delay is used, the instrument will wait the programmed delay period after closing a channel before taking a reading. Thus, the delay period acts as achannel settling time to allow signals to settle before each measurement.

The scan delay (settling time) can be programmed be sending the W command as follows:

Wn

Here, n represents the delay period in mesec, with an allowable range of 0msec to 999.999msec. The factory default value for the delay parameter is 0msec. The instrument will assume that value upon power up, of after a DCL or SDC.

NOTES:

1. An "INTERVAL OVERRUN" error will occur if the programmed interval is too short for the present instrument configuration.
2. The programmed interval also affects the reading rate, as well as the data store interval in the continuous trigger mode.
3. A trigger delay of at least one second should be used with AC measurements.
4. The programmed interval must be longer than the delay time, or an "INTERVAL OVERRUN" error will occur.

3.12.4 Using Data Store with the Scanner

Scanner data can easily be stored within the data store buffer for later recall. The following discussion provides a general outline of programming methods for doing so. Some modification of these methods may be necessary for your particular application.

Scanner Programming

Basically, program the unit as follows:

1. Program the scanner for 2- or 4-pole operation with the O command. For example, for 2-pole mode, send "O0X". Be sure that connections are proper for the selected mode (see paragraph 2.11 for details).
2. Use the N command as required to select the type of scanning operation. To close individual channels, simply send N followed by the appropriate channel number. For step or scan, use N10 through N18, or N20 through N28, as described in paragraph 3.12.1.
3. If you wish to scan at programmed intervals, select a continuous trigger mode, and then select the data store interval with the Q command. For example, send Q500X for a 500msec interval. If you wish to trigger each channel separately, select a one-shot trigger mode. This setup will require one trigger per channel, or one trigger per set of channels, depending on the scanner setup.
4. Program the data store size with the I command. Keep in mind that this value represents the total number of individual channels that will be stored. For example, if you select 400 and are scanning all eight channels, the maximum number of data sets is 50 (400/8 = 50).
5. Trigger the instrument to begin the scanning sequence. The trigger stimulus will depend on on the programmed trigger mode. For example if you are using T2 or T3, send GET to trigger the instrument. Also, if you have programmed the one-shot trigger mode, it will be necessary to trigger the instrument for each channel (step) or set of channels (scan).

Reading Scanned Data

Once data has been scanned and stored, it can be read back from the instrument over the bus. One method to determine when the instrument is finished is to program the unit to generate an SRQ when the data store is one-half full or completely full (M2 or M4). Program the instrument for data store output by sending "B1X" and then request data in the usual manner. If buffer locations and channel numbers are required, use the G6 or G7 data format.

Programming Example

The program below demonstrates basic data store operation with the scanner. The program sets up the instrument for DCV, 3V range, 2-pole mode with eight channels. The unit is also set up to store one channel per interval; the interval is programmed for a value of one second. The total number of readings is set to 80, which will accommodate ten sets of scanner data at eight channels per set.

The program comments on each line are self-explanatory.

PROGRAM	COMMENTS
`10 REMOTE 726`	Put 199 in remote.
`20 DIM A$[25]`	Dimension reading input string.
`30 OUTPUT 726 ;''F0R2X''`	DCV, 3V range.
`40 OUTPUT 726 ;''O0X''`	Select 2-pole mode.
`50 OUTPUT 726 ;''N18X''`	One channel per store interval.
`60 OUTPUT 726 ;''Q1000X''`	One second data store interval.
`70 OUTPUT 726 ;''T2X''`	Continuous GET trigger mode.
`80 OUTPUT 726 ;''I80X''`	Store 80 readings in data store.
`90 OUTPUT 726 ;''M2X''`	SRQ when data store is full.
`100 TRIGGER 726`	Trigger 199.
`110 S = SPOLL (726)`	Get IEEE-488 bus status.
`120 IF NOT BIT(S,1) THEN 110`	Wait for SRQ on data store full.
`130 S = SPOLL(726)`	Clear SRQ.
`140 OUTPUT 726 ''B1N10X''`	Data from data store, stop scan.
`150 OUTPUT 726 ;''G6X''`	Format with locations, channels.
`160 FOR I = 1 TO 80`	Loop for all 80 readings.
`170 ENTER 726 ;A$`	Get 199 reading.
`180 PRINT A$`	Display reading.
`190 NEXT I`	Loop back for next reading.
`200 END`	

3.12.5 Testing Resistors

The Model 1992 Scanner adds versatility to the Model 199 by allowing the unit to test multiple sources. One possible application for the scanner would be to test multiple resistors and compare their values with a precisely known reference resistance. The ratio mode could be used to determine the degree of variability among the various resistors. The following paragraphs discuss connections for 2-pole and 4-pole testing of resistors and also list a sample program for doing so.

Connections

Typical connections for 2-pole and 4-pole modes are shown in Figures 3-10 and 3-11. The 4-pole mode is recommended for making measurements on the 300Ω, 3kΩ, and 30kΩ ranges in order to attain rated accuracy. For the 2-pole mode, the reference resistor should be connected to channel 1 only; in the case of the 4-pole mode, the reference resistor is connected to both channel 1 and 5. The resistors being compared are connected to the remaining channels as indicated.

The scanner output connections also differ. For the 2-pole mode (Figure 3-10), OUT A and OUT B are strapped together (H to H, L to L) and then connected to the VOLTS OHMS terminals of the Model 199 (the rear panel terminals are most convenient for scanner use; just be sure the rear panel terminals are selected with the front panel switch). In the case of the 4-pole connections, OUT A is connected to the VOLTS OHMS terminals, while OUT B is connected to the OHMS SENSE terminals.

Example Program

The program below can be used to test resistors as outlined above. The program will prompt you as to whether the 2-pole or 4-pole mode is to be used and then program the instrument accordingly. In order to use the program, perform the following steps.

1. Connect the resistors to the scanner, as shown in Figure 3-10 or 3-11. For resistances below 30kΩ, the 4-pole mode is recommended for rated accuracy.
2. Enter the lines below into the computer and check the program for errors.
3. Run the program, and select the 2- or 4-pole mode as required.
4. The test will then be run, and the results will be shown on the computer CRT. The results will be shown as a percent of tolerance from the reference resistor connected to channel 1 (and 5 for the 4-pole mode).

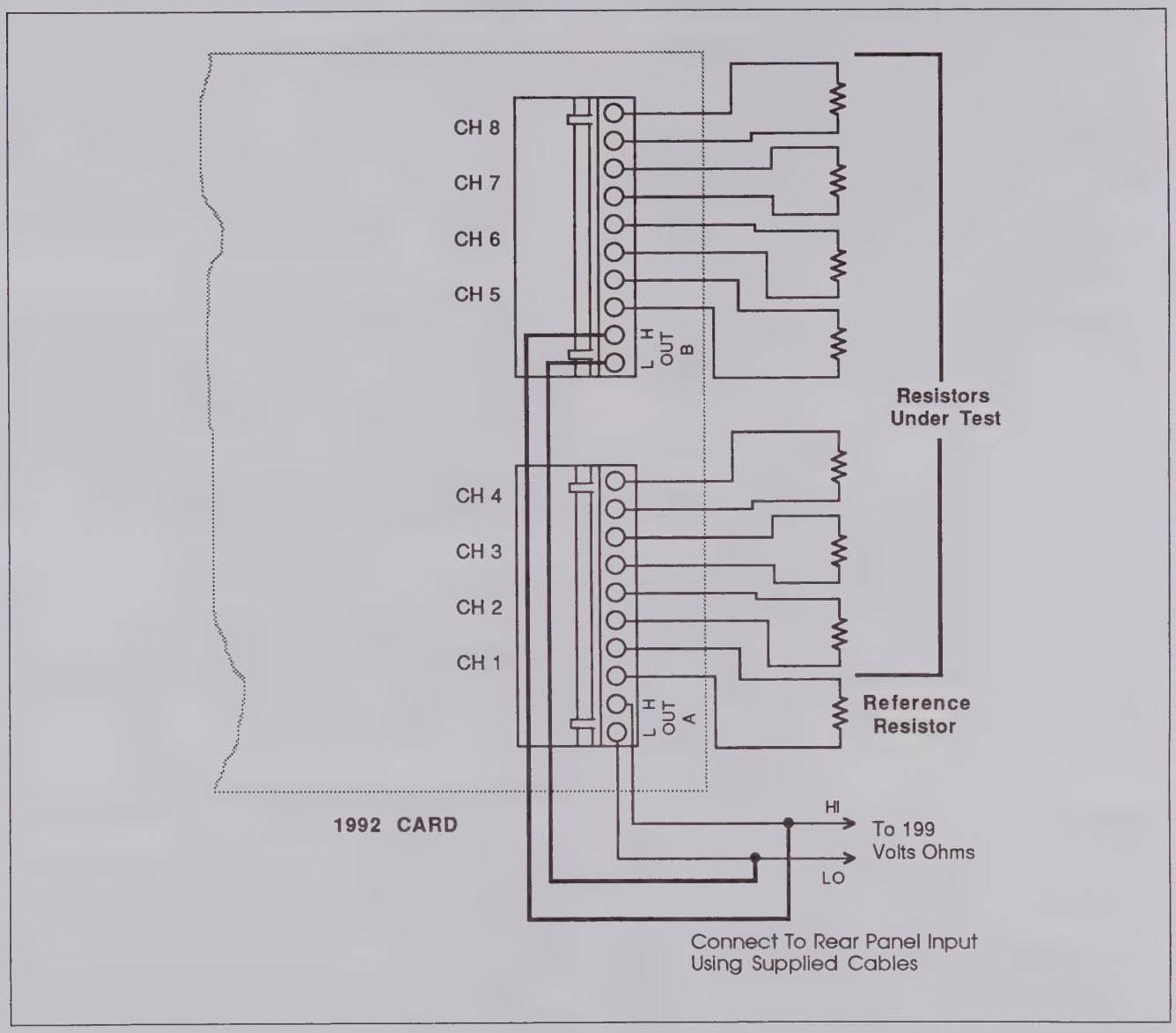


Figure 3-10. 2-Pole Resistor Test Connections

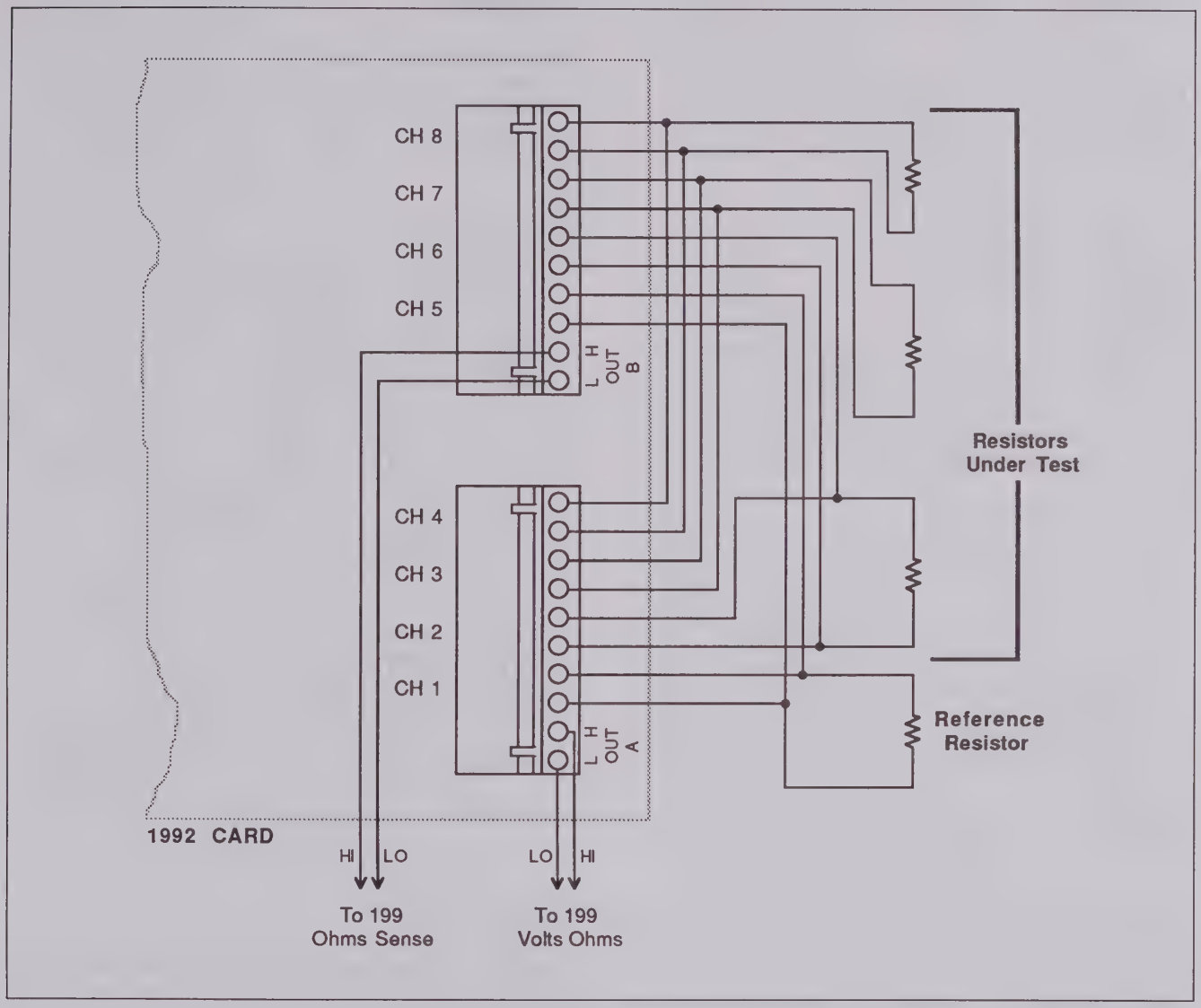


Figure 3-11. 4-Pole Resistor Test Connections

PROGRAM	COMMENTS
`20 CLEAR 726`	Set 199 to default conditions.
`30 OUTPUT 726 ;''F2R3T2X''`	Ohms function, 30k range, GET trig.
`40 OUTPUT 726 ;''Q1000X''`	Store data every second.
`50 PRINT ''1: 2-POLE MODE''`	Prompt for 2- or 4-pole.
`60 PRINT ''2: 4-POLE MODE''`	
`70 PRINT`	
`80 PRINT ''SELECT MODE''`	
`90 INPUT O`	Input mode prompt.
`100 IF O < 1 OR O > 2 THEN 80`	Check response limits.
`110 IF O = 1 THEN N = 8`	Set number of readings depending
`120 IF O = 2 THEN N = 4`	number of poles.
`130 O = O+1`	Define O mode parameter.
`140 OUTPUT 726 ;''N'';N+10;''X''`	Program step mode, limit.
`150 OUTPUT 726 ;''O'';O;''X''`	Program pole/ratio mode.
`160 OUTPUT 726 ;''M2X''`	SRQ when data store is full.
`170 OUTPUT 726 ;''I'';N;''X''`	Number of readings in data store.
`180 PRINT ''PRESS 'CONT' TO BEGIN''`	Prompt to begin data storage.
`190 PAUSE`	
`200 TRIGGER 726`	Trigger 199 to scan and store readings.
`210 PRINT ''SCANNING...''`	
`220 S = SPOLL (726)`	Get IEEE-488 bus status.
`230 IF NOT BIT (S,1) THEN 220`	Wait for SRQ.
`240 S = SPOLL(726)`	Clear SRQ.
`260 OUTPUT 726 ;''G1B1N10X''`	Data store reading,stop scan.
`270 ENTER 726 ;R1`	Get channel 1 reading.
`280 FOR I = 2 TO N`	Loop for all remaining channels.
`290 ENTER 726 ;R`	Get ratio reading from 199.
`300 PRINT ''CH'';I;''TOLERANCE IS'';(R-1)*100;''%''`	Compute and display percent tolerance of resistor.
`310 NEXT I`	Loop back for next channel.
`320 END`	

3.12.6 Amplifier Gain Testing

The scanner can be used to simplify gain testing of amplifiers. As shown in Figure 3-12, a signal generator supplies a test signal to the inputs of all seven amplifiers being tested. Channel 1 of the scanner is connected directly to the signal generator, while channels 2 through 8 of the scanner are connected to the amplifier outputs.

The gain of each amplifier is given as follows:

$$A = \frac{V_{OUT}}{V_{IN}}$$

Thus, the ratio mode of the Model 199/1992 can be used to compute the gain of each amplifier automatically.

Example Program

The example program below can be used to run the amplifier tests described above. In order to use this program, proceed as follows:

1. Enter the program, and check it for errors.
2. Make certain the primary address of the Model 199 is set to 26.
3. Connect the equipment together, as shown in Figure 3-12.
4. Set the signal generator to the desired test frequency (<300kHz) and amplitude.
5. Run the program and select the desired range based on the maximum expected output voltages.
6. The instrument will perform the tests and display the gain values on the computer CRT after all seven amplifiers have been tested.

PROGRAM	COMMENTS
`20 OUTPUT 726 ;''L0X''`	Recall default setup.
`30 OUTPUT 726 ;''F1X''`	Select ACV function.
`40 OUTPUT 726 ;''T2X''`	Continuous, GET trigger mode.
`50 PRINT ''1 - 300MV''`	Select range.
`60 PRINT ''2 - 3V''`	
`70 PRINT ''3 - 30V''`	
`80 PRINT ''4 - 300V''`	
`90 PRINT`	
`100 PRINT ''SELECT RANGE''`	
`110 INPUT R`	Input range.
`120 OUTPUT 726 ;''R'';R;''X''`	Program 199 range.
`130 OUTPUT 726 ;''O2X''`	2-pole ratio mode.
`140 OUTPUT 726 ;''N18X''`	Step, channel 8 limit.
`150 OUTPUT 726 ;''M2X''`	SRQ on data store full.
`160 OUTPUT 726 ;''Q1000X''`	Scan interval is one second.
`170 OUTPUT 726 ;''I8X''`	Store size = 8, turn on store.
`180 PRINT ''PRESS 'CONT' TO BEGIN''`	Pause to make sure all is ready.
`190 PAUSE`	
`200 PRINT ''SCANNING...''`	
`210 TRIGGER 726`	Trigger scan.
`220 STATUS 7,1;S`	Get bus status.
`230 IF NOT BIT(S,10) THEN 220`	Wait for SRQ on store full.
`240 S=SPOLL(726)`	Serial poll to SRQ.
`250 OUTPUT 726 ;''G1X''`	Reading, no prefix data format.
`260 OUTPUT 726 ;''B1X''`	Readings from data store.
`270 ENTER 726 ;A`	Get channel 1 reading.
`280 FOR I = 2 TO 8`	Get gain readings.
`290 ENTER 726 ;A`	Get reading.
`300 PRINT ''AMPLIFIER'';I;''GAIN='';A`	Display gain value.
`310 NEXT I`	Loop back for next reading.
`320 END`	

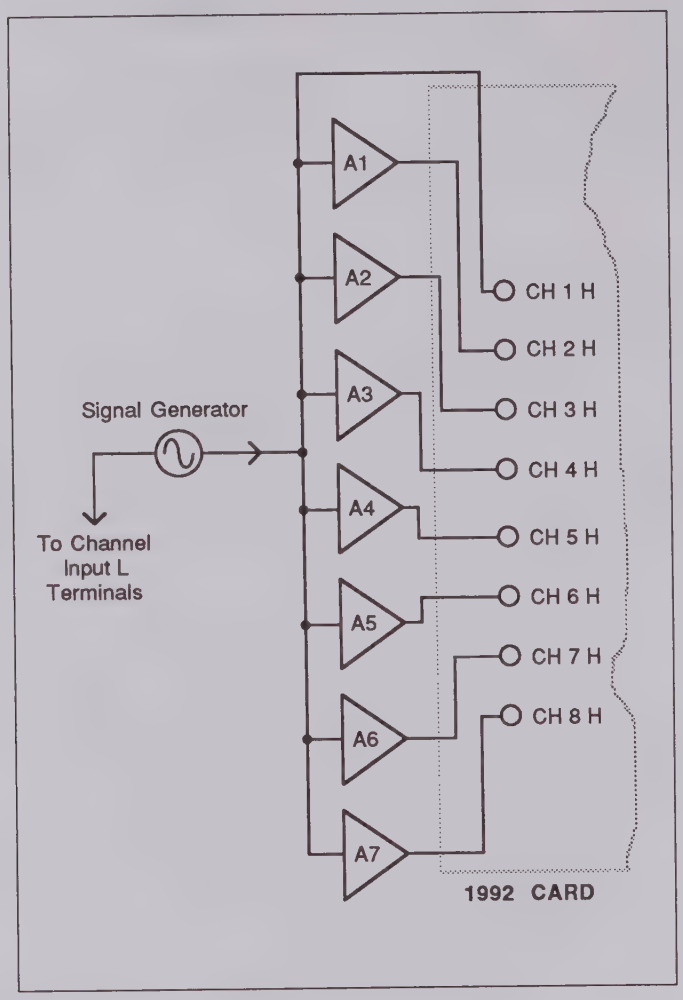


Figure 3-12. Amplifier Gain Test Configurations

SECTION 4
Performance Verification

4.1 INTRODUCTION

The procedures outlined in this section may be used to verify that the instrument is operating within the limits stated in the specifications at the front of this manual. Performance verification may be performed when the instrument is first received to ensure that no damage or misadjustment has occurred during shipment. Verification may also be performed whenever there is a question of instrument accuracy, or following calibration, if desired.

NOTE

If the instrument is still under warranty (less than 1 year from the date of shipment), and its performance falls outside the specified range, contact your Keithley representative or the factory to determine the correct course of action.

4.2 ENVIRONMENTAL CONDITIONS

All measurements should be made at 18 - 28°C (65 - 82°F) and at less than 80% relative humidity.

4.3 INITIAL CONDITIONS

The Model 199 must be turned on and allowed to warm up for at least two hours before beginning the verfication procedures. If the instrument has been subject to extremes of temperature (outside the range specified in paragraph 4.2), additional time should be allowed for internal temperatures to reach normal operating temperature. Typically, it takes one additional hour to stabilize a unit that is 10°C (18°F) outside the specified temperature range.

4.4 RECOMMENDED TEST EQUIPMENT

Table 4-1 lists all test equipment required for verification. Alternate equipment may be used as long as the substitute equipment has specifications at least as good as those listed in the table.

NOTE

The verification limits in this section do not include test equipment tolerance and are based on one year accuracy specifications.

Table 4-1. Recommended Test Equipment

Mfg	Model	Description	Specifications
Fluke	5440A	DC Voltage Calibrator	300mV, 3V, 30V, 300V ranges ±15 ppm.
Fluke	5200A	AC Voltage Calibrator	300mV, 3V, 30V ranges; 20Hz ±0.1%; 50Hz-20kHz 0.02%; 100kHz ±0.33%.
Fluke	5215A	AC Power Amplifier	300V range: 20Hz ±0.12%; 50Hz-20kHz ±0.04%; 100kHz ±0.1%
Fluke	5450A	Resistance Calibrator	300Ω-3MΩ ranges ±15 ppm; 30MΩ ±32 ppm; 300MΩ range ±225 ppm
Valhalla	2500E	Current Calibrator	30mA, 3A ranges ±0.025%

4.5 VERIFICATION PROCEDURES

The following paragraphs contain procedures for verifying the one year accuracy specifications of the instrument, at 5½d resolution, for each of the five measuring functions: DC volts, TRMS AC volts, ohms, TRMS AC amps, and DC amps. These procedures are intended for use only by qualified personnel using accurate and reliable test equipment. If the instrument is out of specifications and not under warranty, refer to Section 6 for calibration procedures.

WARNING

The maximum common-mode voltage (voltage between input low and chassis ground) is 500V peak. Exceeding this value may cause a breakdown in insulation, creating a shock hazard. Some of the procedures in this section may expose the user to dangerous voltages. Use standard safety precautions when such dangerous voltages are encountered.

4.5.1 DC Volts Verification

With the Model 199 set to 5½d resolution, verify the DC volts function as follows:

CAUTION

Do not exceed 300V between the input HI and LO terminals or damage to the instrument may occur.

1. Select the DCV function and autorange.
2. Connect the DC voltage calibrator to the Model 199 as shown in Figure 4-1.
3. Set the calibrator to 0V and enable zero on the Model 199. Verify that the display is reading 000.000mV ±2 counts.

NOTE

Low measurement techniques should be used when checking the 300mV DC range. Refer to paragraph 2.6.5 for low level measurement considerations.

4. Set the calibrator to output +300mV and verify that the reading is within the limits listed in Table 4-2.
5. Disable zero and leave it disabled for the remainder of the DCV verification procedure.
6. Check the 3V, 30V, and 300V ranges by applying the respective DC voltage levels listed in Table 4-2. Verify to see that the reading for each range is within the limits listed in the table.
7. Repeat the procedure for each of the ranges with negative voltages.

Table 4-2. Limits for DC Volts Verification

199 DCV Range	Applied DC Voltage	Allowable Readings (18°to 28°C)
300mV	300.000mV	299.961 to 300.039
3 V	3.00000 V	2.99977 to 3.00023
30 V	30.0000 V	29.9970 to 30.0030
300 V	300.000 V	299.970 to 300.030

NOTE: Repeat procedure for negative voltages.

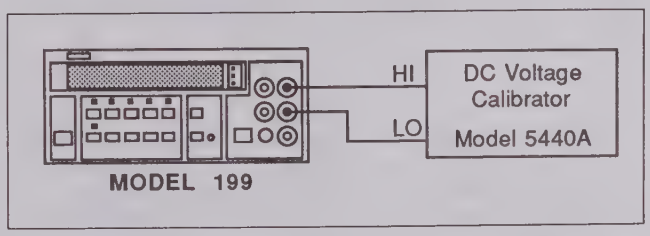


Figure 4-1. Connections for DC Volts Verification

4.5.2 TRMS AC Volts Verification

With the instrument set to 5½d resolution, perform the following procedure to verify the AC volts function:

CAUTION

Do not exceed 300V RMS, 425V peak 10^7V•Hz between the input HI and LO terminals or instrument damage may occur.

1. Select the ACV function and autorange. Do not use zero to cancel the offset in this procedure. Turn zero off, if it is enabled.
2. Connect the AC calibrator to the Model 199 as shown in Figure 4-2.
3. Set the calibrator to output 290mV at a frequency of 20Hz and verify that the reading is within the limits listed in Table 4-3.
4. Repeat the 290mV measurement at the other frequencies specified in Table 4-3.
5. Repeat the procedure for the 3V, 30V and 300V ranges by applying the respective AC voltages listed in Table 4-3. Check to see that the reading for each range is within the limits listed in the table.

Table 4-3. Limits for TRMS AC Volts Verification

199 ACV Range	Applied AC Voltage	Allowable Readings (18°C to 28°C)				
		20Hz	50Hz	200Hz	10kHz	100kHz
300mV	290.000mV	284.100 to 295.900	288.885 to 291.115	289.465 to 290.535	289.465 to 290.535	283.900 to 296.100
3 V	2.90000V	2.84100 to 2.95900	2.88885 to 2.91115	2.89465 to 2.90535	2.89465 to 2.90535	2.85350 to 2.94650
30 V	29.0000V	28.4100 to 29.5900	28.88885 to 29.1115	28.9465 to 29.0535	28.9465 to 29.0535	28.5350 to 29.4650
300 V	290.000V	284.100 to 295.900	288.885 to 291.115	289.465 to 290.535	289.465 to 290.535	*

*Do not apply 290V at 100kHz to the input. This exceeds the V•Hz limit of the instrument. Maximum TRMS AC volt input at 100kHz is 100V. On the 300V range, allowable readings with 100V @ 100kHz applied to the input are 98.200 to 101.800. See paragraph 2.6.7 for clarification of the V•Hz specification.

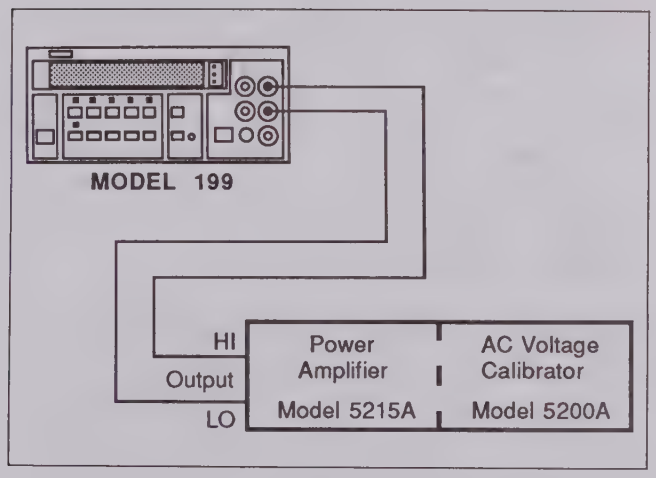


Figure 4-2. Connections for TRMS AC Volts Verification

CAUTION

Do not exceed 425V peak or 300V RMS between the input HI and LO terminals or damage to the instrument may occur.

1. Select the ohms function and autorange.
2. Using Kelvin test leads (such as the Keithley Model 1641) connect the resistance calibrator to the Model 199 as shown in Figure 4-3.
3. Set the calibrator to the SHORT position and enable zero on the Model 199. Verify that the display reads 000.000.
4. Set the calibrator to output 190Ω and verify that the reading is within the limits listed in Table 4-4.
5. Disable zero and leave it disabled for the remainder of the ohms verification procedure.
6. Utilizing Figures 4-3 and 4-4, check the 3kΩ through 300MΩ ranges by applying the respective resistance levels listed in Table 4-4. Verify that the readings are within the limits listed in the table.

4.5.3 Ohms Verification

With the Model 199 set to 5½d resolution, verify the ohms function as follows:

Table 4-4. Limits for Ohms Verification

199 Range	Set up	Applied Resistance	Allowable Readings (18°C to 28°C)
300 Ω	Figure 4-3	190.000 Ω	189.973 to 190.027
3 kΩ	Figure 4-3	1.90000 kΩ	1.89980 to 1.90020
30 kΩ	Figure 4-3	19.0000 kΩ	18.9980 to 19.0020
300 kΩ	Figure 4-4	190.000 kΩ	189.948 to 190.052
3MΩ	Figure 4-4	1.90000MΩ	1.89940 to 1.90060
30MΩ	Figure 4-4	19.0000MΩ	18.9767 to 19.0233
300MΩ	Figure 4-4	100.000MΩ	97.995 to 102.005

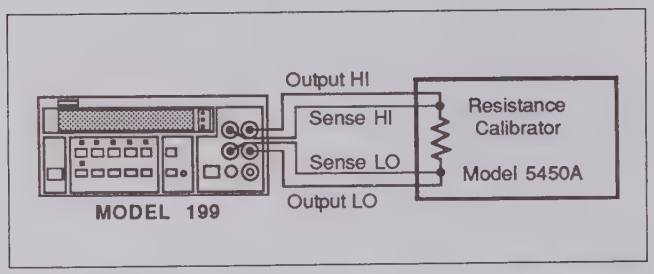


Figure 4-3. Connections for Ohms Verification (300Ω—30kΩ Range)

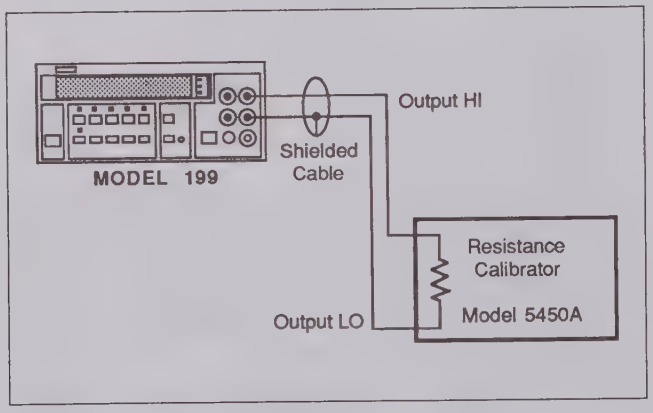


Figure 4-4. Connections for Ohms Verification (300kΩ—300MΩ Ranges)

4.5.4 DC Current Verification

With the instrument set to 5½d resolution, verify the DC current function as follows:

CAUTION
Do not exceed 3A to the AMPS and LO input terminals or the front panel current fuse will blow.

1. Select the DCA function and autorange.
2. Connect the DC current calibration source to the Model 199 as shown in Figure 4-5.
3. Set the calibration source to output +30mA and verify that the reading is within the limits listed in Table 4-5.
4. Repeat the procedure for the 3A range by applying the DC current level listed in Table 4-5. Check to see that the reading is within the limits listed in the table.
5. Repeat the procedure for each of the two ranges with negative current levels.

Table 4-5. Limits for DC Current Verification

199 Range	Applied DC Current	Allowable Readings (18°C to 28°C)
30mA	30.0000mA	29.9835 to 30.0165
3 A	3.00000 A	2.99685 to 3.00315

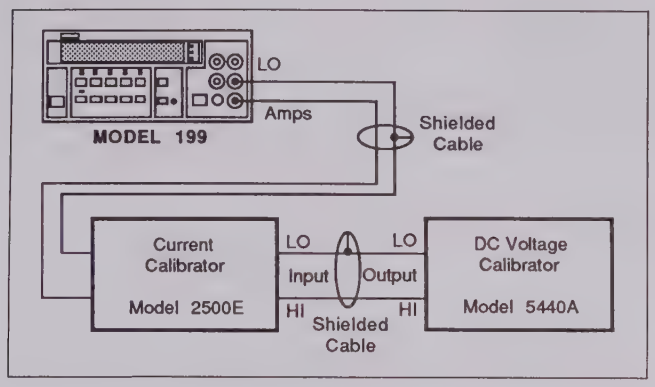


Figure 4-5. Connections for DC Current Verification

4.5.5 TRMS AC Current Verification

With the instrument set for 5½d resolution, verify the AC current function as follows:

CAUTION
Do not exceed 3A to the AMPS and LO input terminals or the front panel current fuse will blow.

1. Select the ACA function and autorange. Do not use zero to cancel any offset in this procedure.
2. Connect the AC current calibration source to the Model 199 as shown in Figure 4-6.
3. Set the calibration source to output 30mA at a frequency of 20Hz and verify that the reading is within the limits listed in Table 4-6.
4. Repeat the 30mA measurement at the other frequencies specified in Table 4-6.
5. Repeat the procedure for the 3A range by applying the AC current level listed in Table 4-6. Check to see that the reading is within the limits listed in the table.

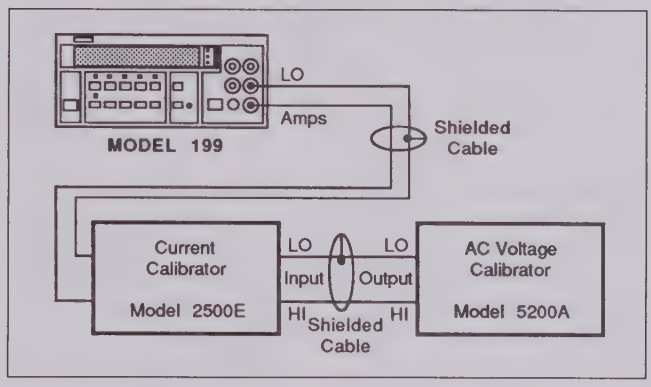


Figure 4-6. Connections for TRMS AC Current Verification

Table 4-6. Limits for AC Current Verification

199 Range	Applied AC Current	Allowable Readings (18°C to 28°C)		
		20Hz	45Hz	10kHz
30mA	29.0000mA	28.4100 to 29.5900	28.8160 to 29.1840	28.8160 to 29.1840
3 A	2.90000A	2.84100 to 2.95900	2.88160 to 2.91840	2.88160 to 2.91840

SECTION 5
Principles of Operation

5.1 INTRODUCTION

This section contains an overall functional description of the Model 199. Detailed schematics and component location drawings are located at the end of this instruction manual.

5.2 OVERALL FUNCTIONAL DESCRIPTION

A simplified block diagram of the Model 199 is shown in Figure 5-1. The instrument may be divided into two sections: analog and digital circuitry. The analog and digital sections are electrically isolated from each other by the use of opto-isolators for control and communications. Separate power supplies for the analog and digital sections ensure proper isolation.

The analog section consists of the signal conditioning circuits, multiplexer, input amplifier, A/D converter and control circuitry. The heart of the digital section is 68B09 microprocessor that supervises the entire operation of the instrument. Additional digital circuitry includes the display and IEEE-488 interface.

If the optional Model 1992 Scanner is installed, it is controlled through the control circuits located on the analog board. Connections to the DMM inputs are supplied by the user.

5.3 ANALOG CIRCUITRY

The detailed circuitry of the Model 199 analog section is located on schematic diagram number 199-126.

5.3.1 Input Signal Conditioning

Signal conditioning circuitry modifies the input to a signal that is usable by the Model 199 and applies that signal to the multiplexer.

DC Volts

Signal conditioning for the 30V and 300V ranges is performed by resistor divider network R17. On these ranges, K1, K2, and K3 are open, and the divider network is connected to signal ground through Q11 and U22A. The following attenuation of the input signal is provided:

Divided by 10 on the 30V range.
Divided by 100 on the 300V range.

On the 30V range, Q13 is on and Q3 is off routing the input signal in the multiplexer (Q35). On the 300V range, Q13 is off and Q3 is on routing the input signal to the multiplexer (Q35). On the 300mV and 3V ranges, the input signal is removed from the resistor divider network (Q13 and Q3 off) and applied directly to the multiplexer through K1 and Q30.

AC Volts

The basic steps involved in ACV conditioning are as follows:

1. Relay K4 applies the ACV input to the gain circuitry. Here the signal undergoes a gain factor of 10 (300mV range), 1 (3V range), 1/10 (30V range) or 1/100 (300V range).
2. The signal is then applied to the TRMS converter (U27) where the AC signal is converted to a DC signal.
3. The DC signal is then applied to the multiplexer.

On the 300mV and 3V ranges, the signal is routed through relay K5 and buffer U28A. On the 3V range, the signal proceeds through analog switch U21C and buffer U26B before being applied to the TRMS converter (U27). On the 300mV range, the signal is detoured through analog switch U23A to U28B which is configured as a X10 amplifier. The amplified signal then proceeds through analog switch U23B and buffer U26B to the TRMS converter (U27).

On the 30V range, the signal is applied to U26A. Because analog switch U21A is open on this range, amplifier U26A has a feedback resistance of 118kΩ (R32) which results in a gain factor of 1/10. The divided signal is then routed through analog switch U21B and buffer U26B to the TRMS converter (U27).

On the 300V range, the signal is applied to U26A. Because analog switch U21A is closed on this range, amplifier U26A has a feedback resistance of 118kΩ (R32) in parallel with 13kΩ (R24), resulting in a gain factor of 1/100. The divided signal is then routed through analog switch U21B and buffer U26B to the TRMS converter (U27).

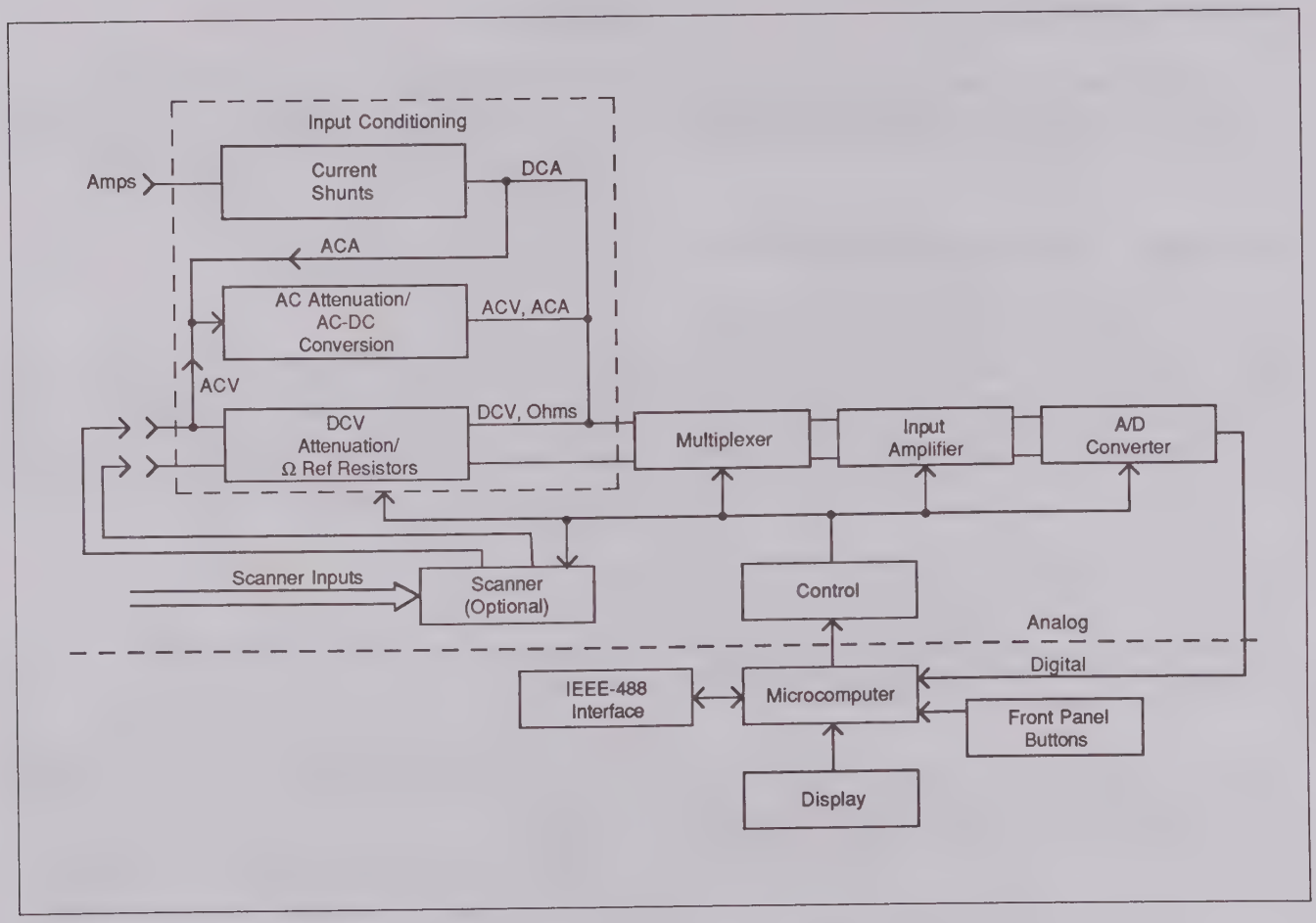


Figure 5-1. Overall Block Diagram

OHMS

Resistance measurements are made using the ratiometric technique (see Figure 5-2). When the resistance function is selected, a series circuit is formed between the ohms source, a reference resistor and the external unknown resistance. A current flows through the reference resistor and the unknown resistance. Since this current is common to both resistances, the value of the unknown resistance can be calculated by measuring the voltage across the reference resistor and the voltage across the unknown resistance.

The following ohms reference resistors are used (see Figure 5-3).

300Ω and 3kΩ ranges: R26 (2kΩ)
30kΩ range: R23 (30kΩ)
300kΩ range: R17B ‖ R17C (100kΩ)
3MΩ range: R17A ‖ R17B (1MΩ)
30MΩ and 300MΩ ranges: R17A (10MΩ)

By measuring the four inputs to the A/D converter the unknown resistance can be computed by the microprocessor using this equation:

$$R_X = \frac{R_{REF} \bullet (V\Omega \text{ SENSE HI} - V\Omega \text{ SENSE LO})}{V\Omega \text{ REF HI} - V\Omega \text{ REF LO}}$$

For the 300Ω range VΩ SENSE HI and VΩ SENSE LO are actually multipled by a factor of 10 in the input buffer circuit.

Protection on the ohms ranges is accomplished by RT1 and Q16. For an input voltage applied to the Ω input terminals, Q16 clamps the voltage to the reference resistors to a safe limit. RT1 limits the current to Q9 and Q16.

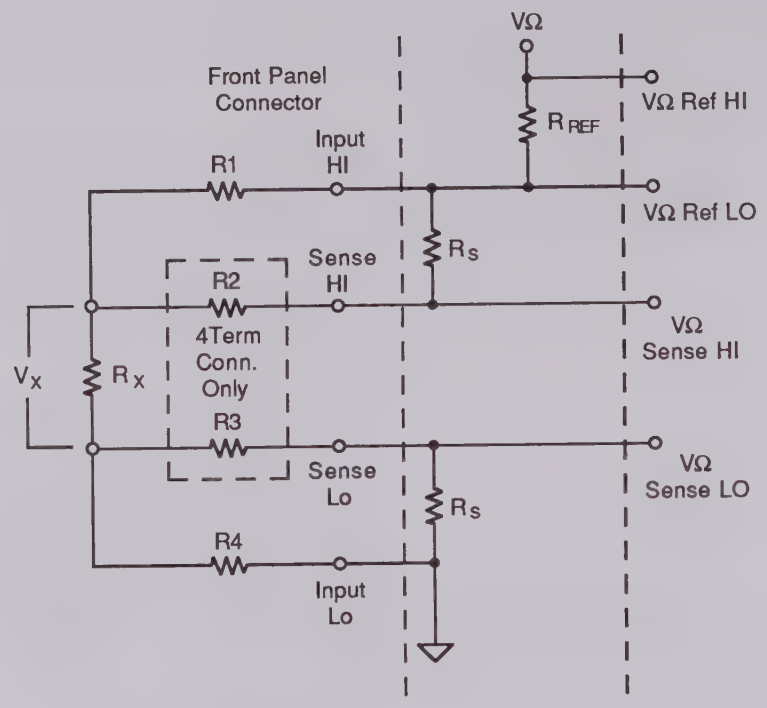
The Model 199 is equipped to make 2- or 4-terminal resistance measurements. Generally, 4-terminal measurements should be made on the 300Ω range because the relatively large output current can develop a significant voltage across the test leads, affecting measurement accuracy.

Figure 5-2 shows the equivalent circuit of the input circuit. R_X is the unknown measured resistance and R1, R2, R3 and R4 represent the test lead resistance. R2 and R3 are connected only during 4-terminal measurements. When using a 2-terminal configuration, all the current flows through the test leads R1 and R4. If R_X has a low value, the amount of voltage developed across the test leads can be significant.

Since the voltage is sensed across the combined resistance of R_1, R_X and R_4; considerable error can be introduced into the reading. To use a 4-terminal connection, a second set of leads (R2 and R3) are connected to the unknown resistance. The amount of current through R2 and R3 is much smaller than the current through R1 and R4. Thus, the voltage seen by the instrument is much closer to the actual value across the measured resistance, minimizing the error.

DC Amps and AC Amps

The resistor current shunt network R75 and R30 is configured so that a full scale current input will result in a 300mV drop across the network on both current ranges. For 30mA DC, this voltage is routed to the multiplexer through U23C and U22B. For 3A DC, this voltage is routed to the multiplexer through Q37 and U22B. For AC Amps, the signal is routed through U23D to X10 amplifier U28B. The amplified signal then travels through analog switch U23B and buffer U26B to the TRMS converter. The converted DC signal is then routed to the multiplexer.



$$R_X = \frac{R_{Ref} \bullet (V\Omega \text{ Sense HI} - V\Omega \text{ Sense LO})}{V\Omega \text{ Ref HI} - V\Omega \text{ Ref LO}}$$

Figure 5-2. Input Configuration During 2 and 4-Terminal Resistance Measurement

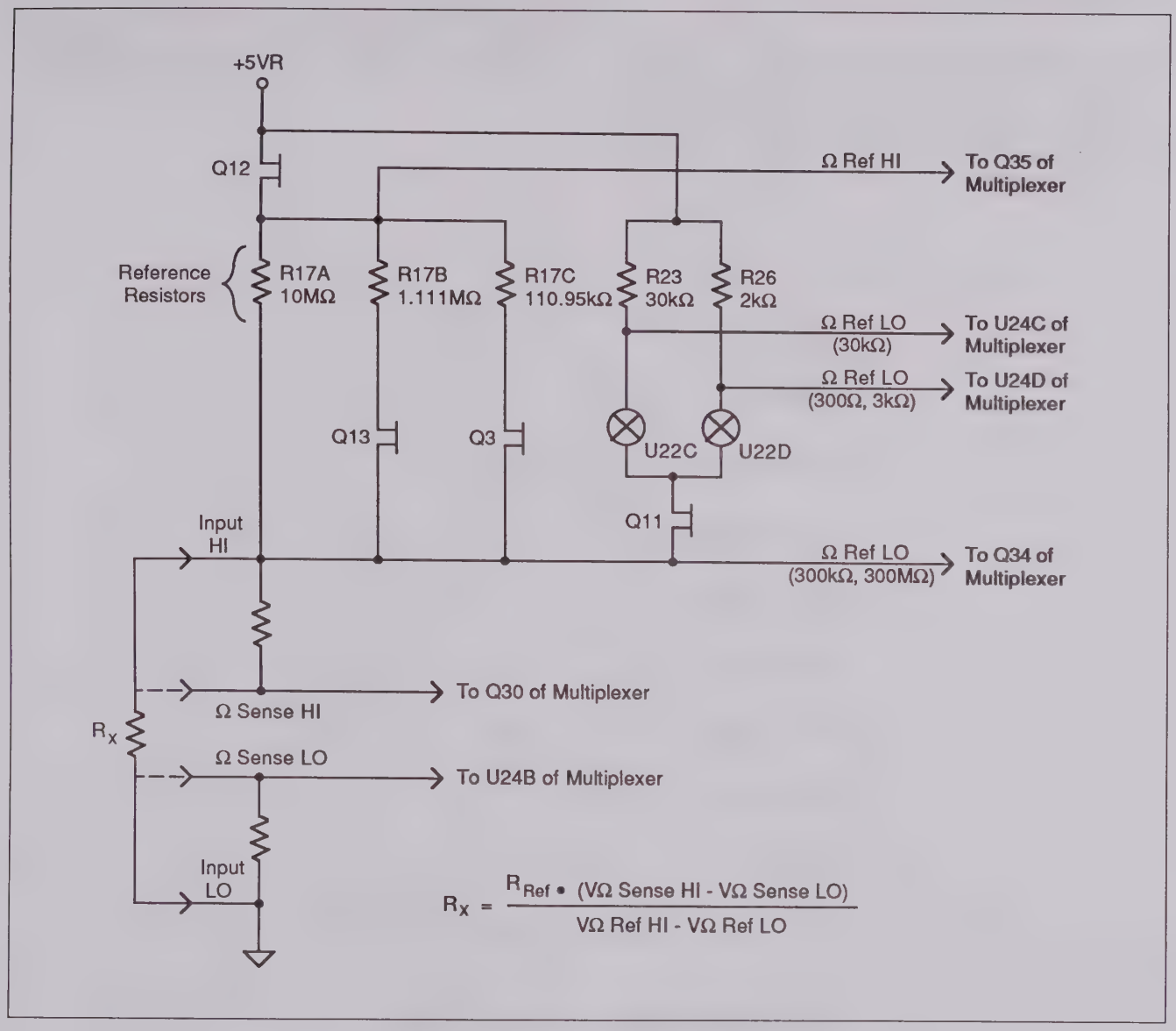


Figure 5-3. Resistance Measurement Simplified Circuitry

5.3.2 Multiplexer

The multiplexer circuitry selects among the various signals that are part of the Model 199 measurement cycle and connects them to the input buffer amplifier. Figure 5-4 shows a simplified schematic of the multiplexer circuitry. The Front/Rear INPUT switch detector U25B is not part of a measurement cycle.

Figure 5-5 shows the general switching phases for the various signals. During each phase, an integration is performed by the A/D converter, and the resultant data is used by the microprocessor to calculate the final reading.

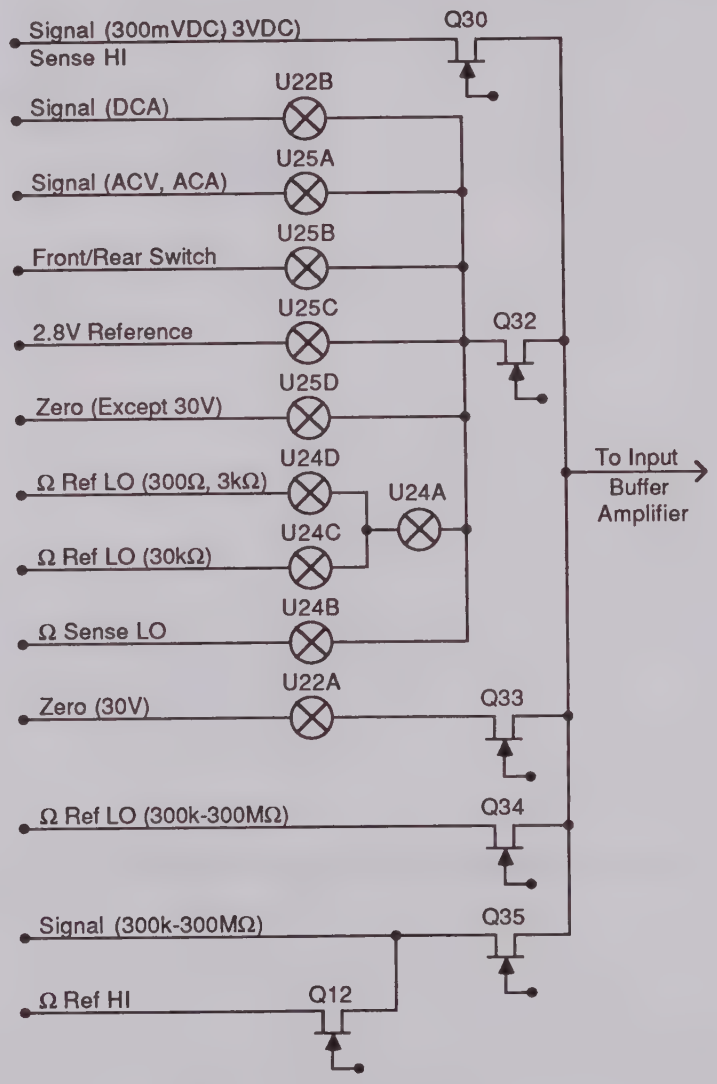
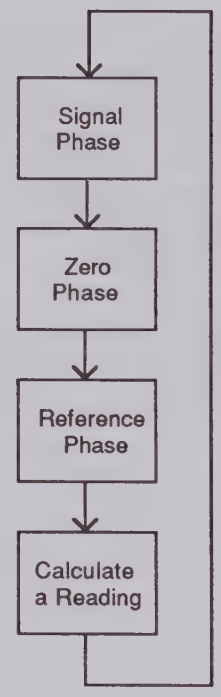
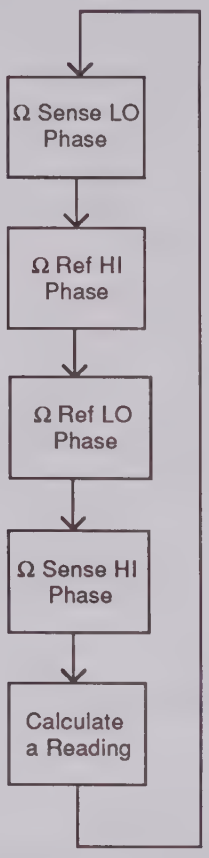


Figure 5-4. JFET Multiplexer



A. Typical Voltage and Current Measurements



B. Typical Resistance Measurements

Figure 5-5. Multiplexer Phases

5.3.3 −2.8V Reference Source

Voltage and current measurements are based on comparing the unknown signal with an internal −2.8V reference voltage source. During each measurement cycle, the unknown signal is sampled and then compared with signal common and the −2.8V reference values.

VR2 provides a highly stable −6.4V reference, while U13 and R66 provide a constant current to minimize zener voltage variations. R68 and R69 divide down the −6.4V value to the final −2.8V reference voltage.

5.3.4 Input Buffer Amplifier

The input buffer amplifier, U46, provides isolation between the input signal and the A/D converter. The amplifier can be configured for X1 or X10 gain with R71 and R64 acting as the feedback network. When X1 gain is selected by the microprocessor, feedback is routed through pin 12 of the analog switch U45A. At X10 gain, feedback is routed through pin 13 of the multiplex switch. Amplifier gain configurations for the various functions and ranges are listed in Table 5-1.

Table 5-1. Input Buffer Amplifier (U46) Gain Configuration

Function	Range	Gain
DC Volts	300mV	X10
	3-300V	X1
AC Volts	All	X1
Ohms	300Ω	X10
	3k-300MΩ	X1
DC Amps	All	X10
AC Amps	All	X1

5.4 A/D CONVERTER

The Model 199 uses a constant frequency, variable pulse width, analog-to-digital converter. A simplified schematic of the A/D used in the Model 199 is shown in Figure 5-6.

The charge balance phase begins when the input enable/disable line is set high. This occurs at the end of a software-generated delay period that allows the signal to settle after the appropriate multiplexer FET is turned on. Once the input is enabled, the signal from the buffer amplifier is added to the level shift current applied through R62C and R61 or R61 only. In this manner, the ±3.03V bipolar signal from the buffer amplifier is converted to a unipolar signal that can be integrated.

The integrator is made up of Q1, U19 and C32. When the input to the integrator is applied, the integrator output ramps up until its voltage is slightly higher than the voltage applied to the inverting input of the duty cycle comparator (U5A). The charge balance current, whose duty cycle is proportional to the input, is fed back to the integrator input through R8 and Q4. Since the charge balance current is much larger than the sum of the input and level shift currents, the integrator output now ramps in the negative direction until Q of U8B goes low. The VIA, located in the microcomputer then counts the total number of pulses that occur during the charge balance phase.

At the end of the charge balance phase, the output of the integrator is resting at some positive voltage. Since the integrator output is connected to the non-inverting input of the final-slope comparator (U5B), the final-slope comparator output remains high until the integrator output ramps in the negative direction. During final-slope, Q4 is turned off and the feedback is fed through U16 back to the integrator input. The final-slope comparator output is then gated with the 3.84MHz clock and counted. Once the comparator output goes low, the VIA stops counting and the reading can be computed.

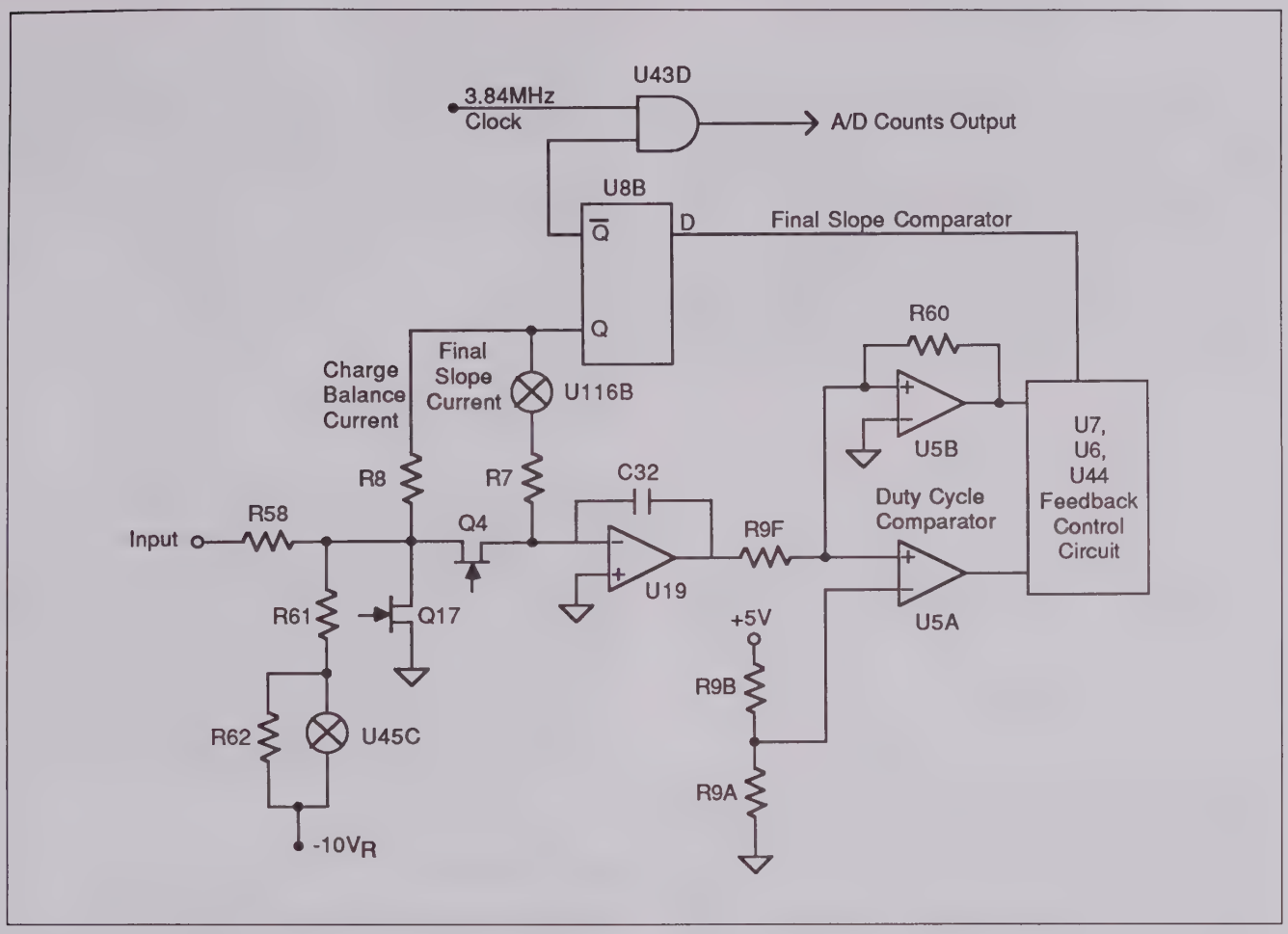


Figure 5-6. A/D Converter Simplified Schematic

5.5 CONTROL CIRCUITRY

The signals for the circuitry that provides control of the various FETs, relays, analog switches and logic levels are supplied by the shift store registers U29, U30, U31, and U32 (see schematic 199-126, page 3). CLOCK, DATA and STROBE signals are sent from the VIA (U8) across the opto-isolators. AT1, AT2, and AT3 (see schematic 199-126, page 5). The isolators provide 500V isolation between the analog and digital sections of the instrument. DATA is serially loaded into the shift store registers and a STROBE pulse causes the registers to simultaneously output the appropriate logic levels to the FET, analog switch and relay drivers.

5.6 DIGITAL CIRCUITRY

The Model 199 is controlled by an internal microcomputer. This section briefly describes the operation of the microcomputer and associated digital circuitry. Refer to schematic diagram number 199-106 for circuit details.

5.6.1 Microcomputer

The microcomputer centers around the 8-bit 68B09 microprocessor. The MPU has direct control over the display, front panel switches, A/D converter, IEEE-488 bus, scanner, as well as the VOLTMETER COMPLETE Output and the EXTERNAL TRIGGER Input. Timing for the micro-processor is accomplished by the use of Y1; an 8MHz crystal. This frequency is divided down by four to obtain a bus operating frequency of 2MHz by the MPU, U10.

Instrument operation software is stored in the EPROM, U4. Calibration constants, Translator words and instrument set up conditions are stored in E²PROM (U20). U9 is the RAM. The chip selected is determined by the state of A11, A12, A13, A14 and A15 address lines. These address lines determine which is selected by the decoder (U1). Only one device (ROM, RAM, VIA, etc) will have access to the data bus at any one time.

The heart of the IEEE-488 circuitry is the General Purpose Interface Bus Adapter (U5). The GPIBA is capable of performing all IEEE talker-listener protocols. The bidirectional data lines D0 through D7 permit the transfer of data between the microprocessor and the GPIBA. The transceivers U6 and U7 are used to drive the output. Data is buffered by U6 and U7 and is transmitted to the bus via connector J7.

5.6.2 Display Circuitry

The display information is sent through display latches U16 and U15. Upon each display update, new segment information is presented to the display latches and a clock pulse is sent on PA0. The clock pulse to U4 and U5 (see schematic 199-116) shifts a digit enable bit to the next digit to be enabled. Every 10 times the display is updated, a digit enable it is generated at PA1 and goes to the data input of the shift register. U11 through U12 are the drivers for the LED segments of the display digits and the LED indicators.

5.7 POWER SUPPLIES

The main power supplies of the Model 199 are located on sheet 5 of schematic drawing number 199-126. Fuse F2 is the line fuse which is accessible from the rear panel. S2 is the POWER ON/OFF switch and S3 selects 115V or 230V operation by placing the transformer primary windings in parallel or series. The power transformer, T1, has three secondary windings; one for the +5V digital supply, one for the +5V analog supply and one for the ±15V analog supply. CR13, CR14 and CR15 provide fullwave rectification for the three supplies, while U50 through U53 provide the regulation. Supply filtering is performed by C56-C60, C63, C65, and C72.

5.8 SCANNER

The optional Model 1992 Scanner Card allows the user to multiplex eight, 2-pole inputs or four, 4-pole inputs. A schematic diagram of the Model 1992 is shown on drawing number 1992-106, located at the end of Section 7. The main sections of the scanner card include the control and relay circuits, as outlined below.

5.8.1 Control Circuitry

Control information for which channel should be closed is transmitted in via the STROBE, DATA, and CLOCK lines into U2. The control sequence is essentially the same as that used for the main DMM circuitry discussed previously. The U2 output for the relay that is to be closed is set low, while the remaining outputs are high so that only one relay is closed at any given time.

U1 and associated components are included in order to ensure that relays do not randomly close during power up.

At power up, the Q output of U1 goes high, disabling the outputs of U2. When the first STROBE pulse comes along, the D-type flip-flop in U1 is cleared, enabling the U2 outputs, and normal relay operation can commence, depending on channel control data.

5.8.2 Switching Relays

Each of the eight input channels has a DPST (double-pole, single-throw) relay associated with it in order to switch the HI and LO terminals separately. The relays are connected in two four-unit groups for maximum versatility in pole switching. Relays K1 through K4 are associated with output A, while relays K5 through K8 are connected to output B. For 2-pole operations, the user must strap the two outputs together (HI to HI, LO to LO), while the outputs must be connected separately for 4-pole operation.

SECTION 6
Maintenance

6.1 INTRODUCTION

This section contains information necessary to maintain, calibrate, and troubleshoot the Model 199. Fuse replacement and line voltage selection procedures are also included.

WARNING
The procedures included in this section are for use only by qualified service personnel. Do not perform these procedures unless qualified to do so. Many of the steps in this section may expose you to potentially lethal voltages that could result in personal injury or death if normal safety precautions are not observed.

6.2 LINE VOLTAGE SELECTION

The Model 199 may be operated from either 105-125V or 210-250V 50 or 60Hz power sources. (A special transformer may be installed for 90-110V and 190-220V ranges). The instrument was shipped from the factory set for an operating voltage
marked on the rear panel. To change the line voltage, proceed as follows:

WARNING
Disconnect the line cord and all other equipment from the Model 199.

1. Place the line voltage switch, located on the rear panel, in the desired position. See Table 6-1 for the correct position.
2. Install a power line fuse consistent with the line voltage. See paragraph 6.3.1 for the fuse replacement procedure.

CAUTION
The correct fuse type must be used to maintain proper instrument protection.

3. Mark the selected line voltage on the rear panel for future reference (to avoid confusion, erase the old mark).

Table 6-1. Line Voltage Selection

Line Voltage	Line Frequency	Switch Setting
105V—125V	50Hz—60Hz	105V—125V
210V—250V	50Hz—60Hz	210V—250V

6.3 FUSE REPLACEMENT

The Model 199 has two fuses for protection in case of overload. The line fuse protects the line power input of the instrument, and the current fuse protects the current function from excessive current. The fuses may be replaced by using the procedures found in the following paragraphs.

WARNING
Disconnect the instrument from the power line and from other equipment before replacing fuses.

6.3.1 Line Fuse

To replace the line fuse, proceed as follows:

1. Turn off the power and disconnect the line cord and all other test cables from the instrument.
2. Place the end of a flat-blade screwdriver into the slot in the line fuse holder on the rear panel. Push in and rotate the fuse carrier one-quarter turn counterclockwise. Release pressure on the holder, and its internal spring will push the fuse and the carrier out of the holder.
3. Remove the fuse, and replace it with the proper type using Table 6-2 as a guide.

CAUTION

Do not use a fuse with a rating higher than specified or instrument damage may occur. If the instrument repeatedly blows fuses, locate and correct the cause of the trouble before replacing the fuse.

4. Install the new fuse and the carrier into the holder by reversing the above procedure.

Table 6-2. Line Fuse Replacement

Line Voltage	Fuse Type	Keithley Part No.
105V–125V	3/16A, 250V, Slo-Blo, 3AG	FU-29
210V–250V	1/10A, 250V, Slo-Blo, 3AG	FU-40

6.3.2 Current Fuse

The current fuse protects the 30mA and 3A ranges from an input current greater than 3A. To replace the current fuse, perform the following steps:

1. Turn off the power and disconnect the power line and test leads.
2. Place the end of a flat-blade screwdriver into the slot in the fuse holder on the front panel. Press in slightly and rotate the fuse carrier one-quarter turn counterclockwise. Release pressure and remove the fuse carrier and the fuse.
3. Remove the defective fuse and replace it using Table 6-3 as a guide.

CAUTION

Use only the recommended fuse type. If a fuse with a higher current rating is installed, instrument damage may occur.

4. To replace the fuse carrier with the fuse, reverse the procedure in step 2.

Table 6-3. Current Fuse Replacement

Fuse Type	Keithley Part No.
3A, 250V, 3AG, Normal-Blo	FU-82

6.4 CALIBRATION

Calibration should be performed every 12 months, or if the performance verification procedures in Section 4 show that the Model 199 is out of specification. If any of the calibration procedures in this section cannot be performed properly, refer to the troubleshooting information in this section. If the problem persists, contact your Keithley representative or the factory for further information.

NOTE

Check that the instrument is set to the proper line frequency before proceeding with calibration.

The entire calibration procedure may be performed without having to make any internal adjustments if high frequency (70kHz) has been verified, as explained in paragraph 6.4.10, step 5. Calibration can be performed from the front panel or over the IEEE-488 bus.

NOTE

A "CONFLICT" error will be displayed, and the CONFLICT error bit in the U1 status word will be set when trying to calibrate the instrument while it is in an improper state (i.e. dB). Also, if an "UNCAL" error occurs, be sure to check the line frequency setting before performing calibration.

6.4.1 Recommended Calibration Equipment

Table 6-4 lists recommended calibration equipment. Alternate equipment may be used as long as equipment accuracy is at least as good as the specifications listed in the table.

Table 6-4. Recommended Calibration Equipment

Mfg	Model	Description	Specifications
Fluke	5440A	DC Voltage Calibrator	300mV, 3V, 30V, 300V ranges ±15ppm
Fluke	5200A	AC Voltage Calibrator	300mV, 3V, 30V ranges; 20Hz ±0.1%; 50Hz—20kHz 0.02%; 100kHz ±0.33%
Fluke	5215A	AC Power Amplifier	300V range; 20Hz ±0.12%; 50Hz—20kHz ±0.04%; 100kHz ±0.1%
Fluke	5450A	Resistance Calibrator	300Ω—3MΩ ranges; ±15ppm; 30MΩ ±32ppm; 300MΩ ±225ppm
Valhalla	2500E	Current Calibrator	30mA, 3A ranges ±0.025%

6.4.2 Environmental Conditions

Calibration should be performed under laboratory conditions having an ambient temperature of 23°C ±1°C and a relative humidity of less than 70%.

6.4.3 Warm-Up Period

Turn on the instrument power and allow it to warm up for at least two hours before beginning the calibration procedure. If the instrument has been subjected to extremes of temperature or humidity, allow at least one additional hour for the instrument to stabilize before beginning the calibration procedure.

6.4.4 CAL LOCK Switch

Upon power up, calibration is automatically locked out. A CAL LOCK switch, accessible from the front panel, disables or enables front panel and IEEE-488 bus calibration. When calibration is disabled, calibration cannot be performed. The following message will be briefly displayed when attempting to enter the calibration program while the switch is disabled:

CAL LOCKED

Calibration can only be accomplished with calibration enabled.

To enable calibration, push in on the CAL LOCK switch with an insulated tool (through the small access hole under the round label). The instrument will briefly display the following message:

CAL UNLOCK

After calibration is complete, press in on CAL LOCK a second time in order to disable calibration. The unit will then display the "CAL LOCKED" message.

NOTE

The two decimal points in the function area of the display will be on when calibration is enabled.

6.4.5 Front Panel Calibration

The following information provides the basic procedure for calibrating the instrument from the front panel. A detailed calibration procedure is located in paragraph 6.4.7.

NOTE

DCV ranges have three cal points: minus full range, plus full range, and zero. The remaining functions require only two cal points.

1. Place the unit in the "CAL UNLOCK" state to enable calibration. The switch is accessed from the front panel of the instrument through the access hole.
2. Select the function and range to be calibrated (DC VOLTS, AC VOLTS, OHMS, DC AMPS, or AC AMPS), 5½ digit resolution, zero off, and filter off.
3. Select the front panel calibration program as follows:
   A. Press SHIFT LOCAL. The following message will be displayed briefly:

      CAL=

   B. The default calibration point, which is a high end reading for the selected range and function, will now be displayed. For example, if the 3V DC range was selected in step 2, the following calibration point will be displayed:

      −3.00000 VDC

4. If a different calibration point is to be used, enter the new value using the data buttons (0 through 9). Each press of a data button displays the number at the cursor location (identified by the bright flashing digit), and moves the cursor to the next digit. If the cursor is moved past the least significant digit, it will move back to the most significant digit.
5. Connect the calibration signal to the instrument.
6. Press the NEXT button. The following message will be displayed for several seconds:

   WORKING

7. For DCV ranges only, the plus full range value will be displayed:

   3.00000 VDC

8. Key in the calibration value if different, and connect the calibration signal. Press NEXT.
9. The low end calibration point will now be displayed. For the 3VDC range, the following calibration point will be displayed:

   0.00000 VDC

10. If a calibration point other than the one displayed is to be used, then change the display to the desired value as explained in step 4.
11. Set the level of the calibration signal to agree with the displayed calibration point.
12. Press the NEXT button. The following message will be displayed for several seconds:

    WORKING

13. The calibration points will be stored in E²PROM and the instrument will now exit the calibration program. Select the next range and function to be calibrated and repeat steps 3 through 12.

    NOTE: If the calibration source has an offset, set the calibration points to agree with the actual output of the source. For example, if the source has a 1μV DC offset on the 300mV DC range, set the calibration points for 300.001mV and 000.001mV.

6.4.6 IEEE-488 Bus Calibration

IEEE-488 bus calibration is performed in a manner similar to front panel calibration, except that calibration constants are transmitted over the bus instead of being entered from the front panel. By combining appropriate IEEE-488 compatible calibration equipment with a suitable test program, calibration of the Model 199 could be performed on an automated basis. Refer to Section 3 for complete information on using the IEEE-488 bus. The following information provides the basic procedure for calibrating the instrument over the IEEE-488 bus. The detailed calibration procedure starts with paragraph 6.4.7.

Use the following basic procedure when calibrating the Model 199 over the IEEE-488 bus:

1. Place the unit in the "CAL UNLOCK" state. The CAL LOCK switch is accessed from the front panel of the Model 199.
2. Program the desired range and function over the bus. For example, to select the 300V DC range, send F0R4X.
3. Program zero off, and 5½ digit resolution by sending Z0S1X.
4. The high end of the range is calibrated first. Apply a full range (or near full range) calibration signal to the input of the instrument. For example, for the 300V DC range, apply 300V DC to the instrument.
5. Send the required calibration value preceded by the V command letter and followed by the first calibration command.
   A. For DCV ranges, send C2 first. For example, send V−300XC2X.
   B. For all other functions, send C0 first. For example, send V300XC0X.

   NOTE: Calibration can be aborted at this time by sending an SDC or DCL command over the bus. The calibration constant sent in step 4 will not be stored in E²PROM.

6. The low end of the range is calibrated next. Apply a zero (or near zero) calibration signal to the input of the instrument. For example, for the 300V DC range apply 0V to the instrument.
7. Send the appropriate calibration commands for the second (or third with DCV) calibration point. For example, to calibrate the zero calibration point of the 300V DC range send V0XC1X. Note that C1 is used for the second calibration point.
8. Storage of the two calibration points into E²PROM automatically occurs when the second calibration command is sent.
9. Repeat steps 1-8 for the remaining ranges and functions.

Programming Example—The following simple program demonstrates how to calibrate the Model 199 over the bus. The program assumes that the instrument's primary address is at 26.

PROGRAM	COMMENTS
`10 REMOTE 726`	Send remote enable.
`30 PRINT ''APPLY CALIBRATION SIGNAL''`	Prompt for calibration signal.
`40 PRINT ''ENTER CALI BRATION COMMAND''`	Prompt for command.
`50 INPUT A$`	Input command string from keyboard.
`60 OUTPUT 726;A$`	Send command string to 199.
`70 ENTER 726;B$`	Get a reading.
`80 PRINT B$`	Display reading.
`90 GOTO 30`	Loop back.
`100 END`	

To run the program, press the RUN key. At the prompt, apply a calibration signal to the instrument, type in the corresponding calibration command and press the return key. The computer CRT will then display the calibration value.

6.4.7 Calibration Sequence

Calibrate the Model 199 in the order presented in the following paragraphs. The basic sequence is:

1. DC Volts calibration
2. Ohms calibration
3. AC Volts calibration
4. DC Current calibration
5. AC Current calibration

6.4.8 DC Volts Calibration

To calibrate the DCV function, proceed as follows:

NOTE

For front panel calibration, omit step 4 of the following procedure. For IEEE-488 bus calibration, omit step 3.

1. Select the DC VOLTS function and the 300mV range.
2. Connect the DC calibrator to the instrument as shown in Figure 6-1 (300mV range only; use Figure 6-2 for 3V-300V ranges).

NOTE

Low level measurement techniques should be used when calibrating the 300mV DC range. Refer to paragraph 2.6.5 for low level measurement considerations.

3. For front panel calibration, press SHIFT LOCAL and proceed as follows:
   A. With the −300.000mV DC calibration point displayed on the Model 199, set the DC calibrator to output −0.300000V.
   B. After allowing sufficient time for the calibrator voltage to settle, press the NEXT button. The following message will be displayed for several seconds:

      WORKING

   C. With the 300.000mV DC calibration point displayed, set the DC calibrator output to +0.30000V.
   D. After allowing the voltage to settle, press NEXT. The following message will be displayed:

      WORKING

   E. With the 000.000mV DC calibration point displayed, set the DC calibrator to output 0.000000V.
   F. After allowing sufficient time for the calibrator voltage to settle, press the NEXT button. The following message will be displayed for several seconds:

      WORKING

   G. The instrument will exit the calibration program and return to the 300mVDC range.
   H. Repeat the procedures in step 3 for the remaining DCV ranges using Table 6-5 as a guide. Figure 6-2 shows connections for the 3V-300V ranges.
4. For IEEE-488 bus calibration, proceed as follows:
   A. Set the DC voltage calibrator to output −0.300000V.
   B. After allowing sufficient time for the calibrator voltage to settle, send the following commands over the bus: V−300E−3XC2X.
   C. Set the calibration to +0.30000V.
   D. After allowing the calibrator voltage to settle, send the following commands over the bus: V300E−3XC1X.

E. Set the DC voltage calibrator to output 0.00000V.

F. After allowing sufficient time for the calibrator voltage to settle, send the following command over the bus: V0XC1X. All calibration constants will be automatically stored in E²PROM.

G. Repeat steps A through D for the remaining DCV ranges using Table 6-5 as a guide.

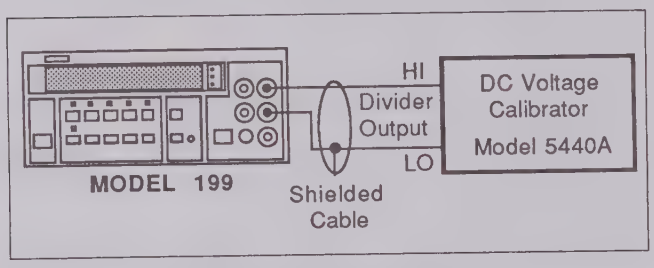


Figure 6-1. DC Volts Calibration Configuration (300mV Range)

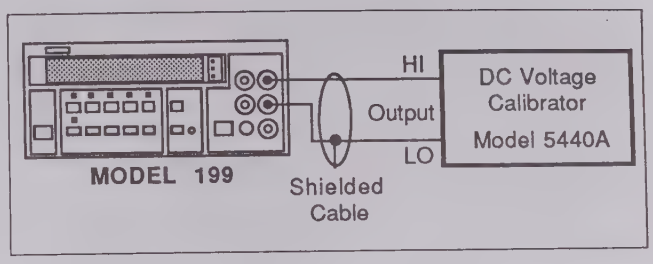


Figure 6-2. DC Volts Calibration Configuration (3V-300V Ranges)

6.4.9 Resistance Calibration

To calibrate the ohms function, proceed as follows:

NOTE

For front panel calibration, omit step 4 of thefollowing procdure. For IEEE-488 bus, calibration, omit step 3.

Table 6-5. DC Volts Calibration

199 DCV Range	Set-Up	199 Calibration Point (DCV)	DC Calibrator Setting	IEEE-488 Bus Command
300mV	Figure 6-1	−300.000mV	−.300000V	V−300E−3XC2X
		300.000mV	.300000V	V300E−3XC0X
		000.000mV	.000000V	V0XC1X
3 V	Figure 6-1	−3.00000 V	−3.00000V	V−3XC2X
		3.00000 V	3.00000V	V3XC0X
		0.00000 V	0.00000V	V0XC1X
30 V	Figure 6-2	−30.0000 V	−30.0000V	V−30XC2X
		30.0000 V	30.0000V	V30XC0X
		00.0000 V	00.0000V	V0XC1X
300 V	Figure 6-2	−300.000 V	−300.000V	V−300XC2X
		300.000 V	300.000V	V300XC0X
		000.000 V	000.000V	V0XC1X

1. Select the ohms function and the 300Ω range.
2. Connect the resistance calibrator to the instrument as shown in Figure 6-3.
3. For front panel calibration, press SHIFT LOCAL and proceed as follows:
   A. With the 190.000Ω calibration displayed on the Model 199, set the resistance calibrator to 190Ω.
   B. After allowing sufficient time for the calibrator resistance to settle, press the NEXT button. The following message will be displayed for several seconds:

      WORKING

   C. With the 000.000Ω calibration point displayed, set the resistance calibrator to SHORT (0Ω).
   D. After waiting sufficient time for the calibrator resistance to settle, press the ENTER button. The following message will be displayed fro several seconds:

      WORKING

   E. The instrument will exit the calibration program and return to the 300Ω range.
   F. Repeat the procedures in step 3 for the remaining ohms ranges using Table 6-6 as a guide.
4. For IEEE-488 bus calibration, proceed as follows:
   A. Set the resistance calibrator to 190Ω.
   B. After allowing sufficient time for the resistance calibrator to settle, send the following commands over the bus: V190XC0X.
   C. Set the resistance calibrator to SHORT (0Ω).
   D. After allowing sufficient time for the resistance calibrator to settle, send the following command over the bus:V0XC1X. Both calibration constants will be automatically stored in E²PROM.

E. Repeat steps A through D for the remaining ohms ranges using Table 6-6 as a guide.

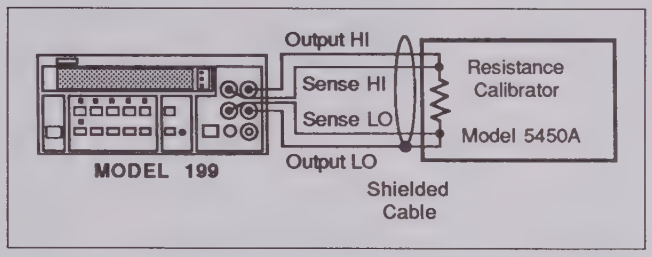


Figure 6-3. Four-Wire Resistance Calibration Configuration (300Ω-30kΩ Ranges)

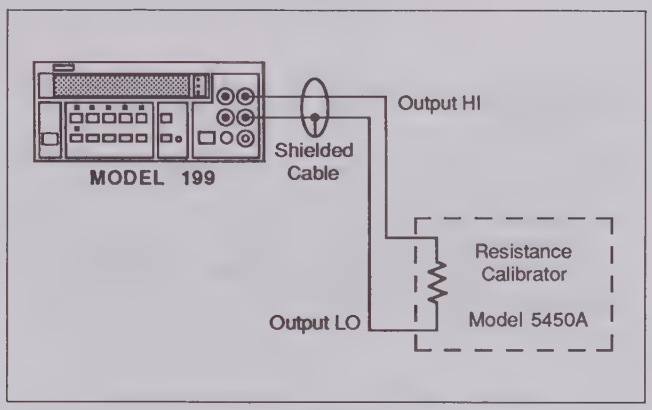


Figure 6-4. Two-Wire Resistance Calibration Configuration (300kΩ-300MΩ Ranges)

Table 6-6. Resistance Calibration

199 Range	Set-Up	199 Calibration Point	Resistance Calibrator Setting	IEEE-488 Bus Commands
300 Ω	Figure 6-3	190.000 Ω	190Ω	V190CX0X
		000.000 Ω	Short (0Ω)	V0XC1X
3 kΩ	Figure 6-3	1.90000 kΩ	1.9kΩ	V1.9E3XC0X
		0.00000 kΩ	Short (0Ω)	V0XC1X
30 kΩ	Figure 6-3	19.0000 kΩ	19kΩ	V19E3XC0X
		00.0000 kΩ	Short (0Ω)	V0XC1X
300 kΩ	Figure 6-4	190.000 kΩ	190kΩ	V190E3XC0X
		000.000 kΩ	Short (0Ω)	V0XC1X
3MΩ	Figure 6-4	1.90000MΩ	1.9MΩ	V1.9E6XC0X
		0.00000MΩ	Short (0Ω)	V0XC1X
30MΩ	Figure 6-4	19.0000MΩ	19MΩ	V19E6XC0X
		00.0000MΩ	Short (0Ω)	V0XC1X
300MΩ	Figure 6-4	100.00MΩ	100MΩ	V100E6XC0X
		000.00MΩ	Short (0Ω)	V0XC1X

6.4.10 TRMS AC Volts Calibration

A full calibration of the ACV function includes two internal, manual adjustments. However, if high frequency is checked and found to be within specifications, the internal adjustments on the 30VAC and 300VAC ranges will not have to be done. The following procedure includes these checks. The flowchart in Figure 6-5 helps clarify the calibration procedure.

NOTE

For front panel calibration, omit step 4 of the following procedure. For IEEE-488 bus calibration, omit step 3.

1. Select the ACV function and the 300mV range.
2. Connect the AC calibrator as shown in Figure 6-6.
3. For front panel calibration, press SHIFT LOCAL, and proceed as follows:
   A. With the 300.000mV AC calibration point displayed on the Model 199, set the AC calibrator to output 300.000mV at 500Hz.
   B. After allowing sufficient time for the calibrator voltage to settle, press the NEXT button. The following message will be displayed for several seconds.

   WORKING

   C. With the 030.000mV AC calibration point displayed, set the AC calibrator to output 30.000mV at 500Hz.
   D. After allowing the calibrator voltage to settle, press the NEXT button. The following message will be displayed for several seconds:

   WORKING

   E. The instrument will exit the calibration program and return to the 300mV AC range.
   F. Repeat the procedures in step 3 for the remaining ACV ranges using Table 6-7 as a guide.
4. For IEEE-488 bus calibration, proceed as follows:
   A. Set the AC voltage calibrator to output 300.000mV at 500Hz.
   B. After allowing sufficient time for the calibrator voltage to settle, send the following commands over the bus: V300E−3XC0X.
   C. Set the AC calibrator to output 30.000mV at 500Hz.
   D. After allowing sufficient time for the calibrator voltage to settle, send the following command over the bus: V30E−3XC1X. Both calibration constants will automatically be stored in E²PROM.
   E. Repeat steps A through D for the remaining ACV ranges using Table 6-7 as a guide.
5. High Frequency Check (70kHz):
   A. With the AC VOLTS function, autorange and 5½d resolution selected, connect the AC calibrator to the instrument as shown in Figure 6-6.
   B. Set the AC calibrator to output 100.000V at a frequency of 70kHz and allow sufficient time for the measurement to settle.
   C. If the reading is not 100.000V ±1800 counts, then omit steps D through E and proceed to step 6.

Table 6-7. TRMS AC Volts Calibration

199 ACV Range	199 Calibration Point	AC Calibrator Voltage Setting @ 500Hz	IEEE-488 Bus Commands
300mV	300.000mV	300.000mV	V300E–3XC0X
	030.000mV	30.000mV	V30E–3XC1X
3 V	3.00000 V	3.00000 V	V3XC0X
	0.30000 V	.300000 V	V300E–3XC1X
30 V	30.0000 V	30.0000 V	V30XC0X
	3.0000 V	3.00000 V	V3XC1X
300 V	300.000 V	300.000 V	V300XC0X
	30.000 V	30.0000 V	V30XC1X

D. Set the AC calibrator to output 10.0000V at 70kHz and allow the measurement to settle.

E. If the reading is not 10.0000V ±1800 counts, then high frequency will have to be adjusted as explained in the following procedure (step 6). If the high frequency readings were within the defined range, step 6 does not have to be performed and ACV calibration is completed.

6. High Frequency Adjustment:

A. Remove the top cover to gain access to the adjustments.

B. With the AC VOLTS function and 5½d resolution selected, connect the AC calibrator to the instrument as shown in Figure 6-6.

C. Set the Model 199 to the 300V range and set the AC calibrator to output 100.000V at a frequency of 70kHz.

WARNING

Some procedures require the use of high voltage. Take care to prevent contact with live circuits which could cause electrical shock resulting in injury or death. The shield on the analog board is at input low potential and may have up to 500V on it. Use an insulated alignment tool to make the following adjustments.

D. After allowing sufficient time for the measurement to settle, use an insulated alignment tool to adjust the 300V range capacitor C48 (see Figure 6-7) for a display reading of 100.000V ±500 counts.

NOTE

If the optional Model 1992 Scanner is installed, the adjustments are accessible through holes in the Scanner board.

E. Set the Model 199 to the 30V range and set the AC calibrator to output 10.0000V at 70kHz.

F. After allowing the measurement to settle, adjust the 30V range capacitor C49 for a display reading of 10.0000V ±500 counts.

G. Repeat steps C through F until no other adjustments need to be made.

H. Put the top cover back on.

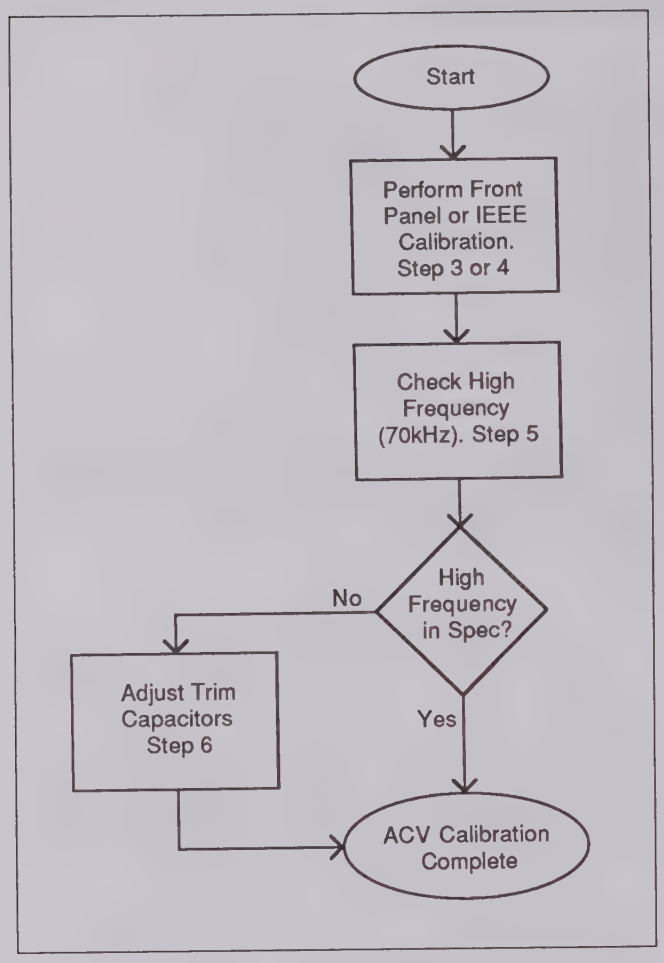


Figure 6-5. Flowchart of AC Volts Calibration Procedure

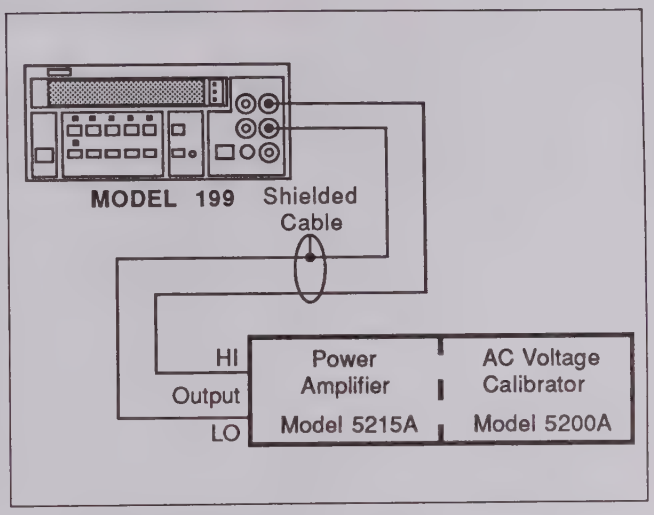


Figure 6-6. TRMS AC Volts Calibration Configuration

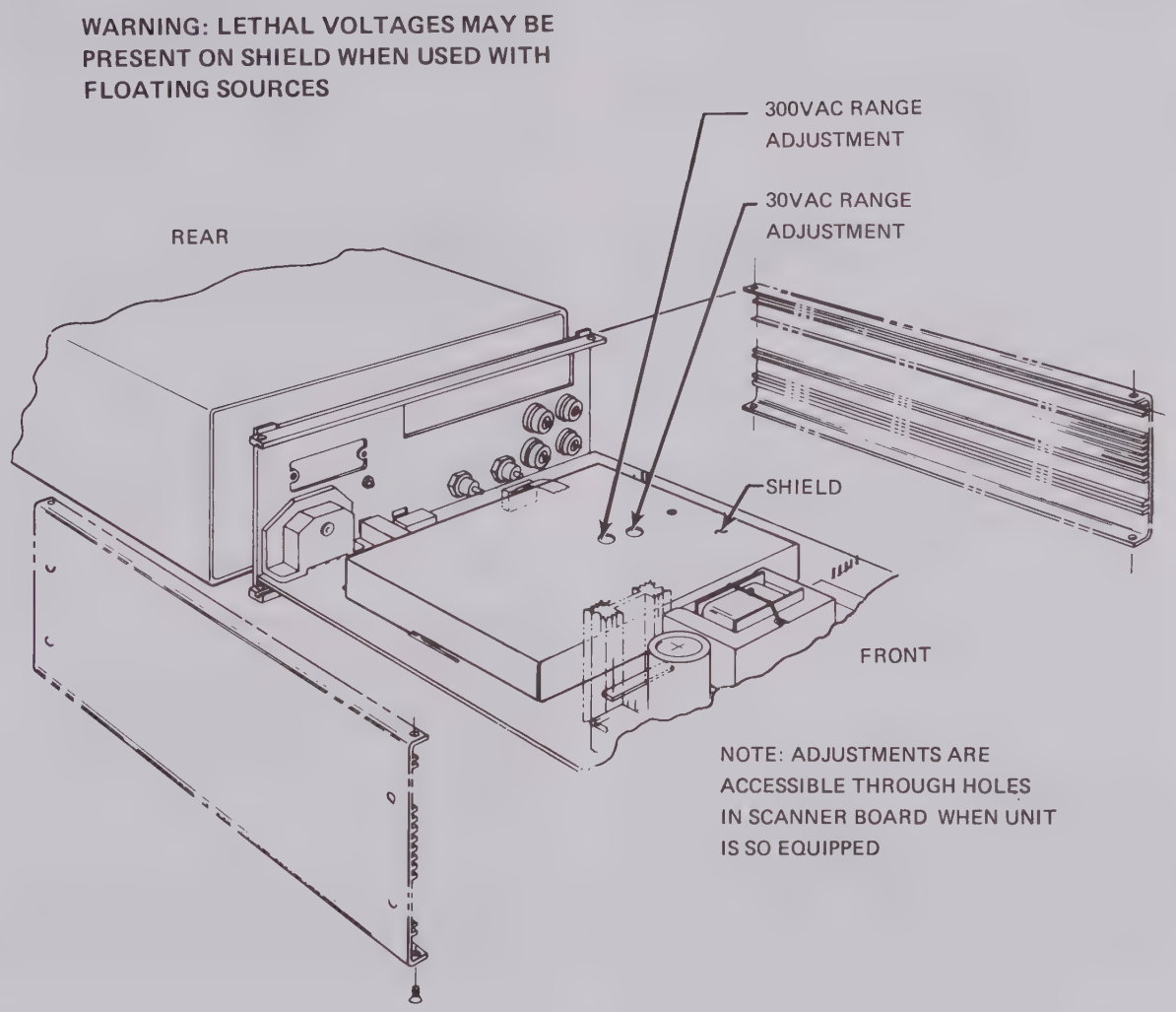

WARNING: LETHAL VOLTAGES MAY BE PRESENT ON SHIELD WHEN USED WITH FLOATING SOURCES
300VAC RANGE ADJUSTMENT
30VAC RANGE ADJUSTMENT
REAR
SHIELD
FRONT
NOTE: ADJUSTMENTS ARE ACCESSIBLE THROUGH HOLES IN SCANNER BOARD WHEN UNIT IS SO EQUIPPED

Figure 6-7. TRMS AC Volts High Frequency Calibration Adjustments (30V and 300V Ranges)

6.4.11 DC Current Calibration

Perform the following procedure to calibrate DCA:

NOTE

For front panel calibration, omit step 4 of the following procedure. For IEEE-488 bus calibration, omit step 3.

1. Select the DC AMPS function and the 30mA range.
2. Connect the DC current calibrator to the instrument as shown in Figure 6-8.
3. For front panel calibration, press SHIFT LOCAL, and proceed as follows:
   A. With the 30.0000mA DC calibration point displayed on the Model 199, set the current calibrator to output +30.0000mA.
   B. After allowing sufficient time for the measurement to settle, press the NEXT button. The following message will be displayed for several seconds:

      WORKING

   C. With the 00.0000mA DC calibration point displayed, set the current calibrator to output 00.0000mA.
   D. After allowing sufficient time for the measurement to settle, press the NEXT button. The following message will be displayed for several seconds:

      WORKING

   E. The instrument will exit the calibration program and return to the 30mA range.
   F. Repeat the procedures in step 3 for the 3A DC range using Table 6-8 as a guide.
4. For IEEE-488 bus calibration, proceed as follows:
   A. Set the current calibrator to output 30.0000mA.
   B. After allowing sufficient time for the calibrator current to settle, send the following command over the bus: V30E-3XC0X.
   C. Set the current calibrator to output 00.0000mA.
   D. After allowing sufficient time for the calibrator current to settle, send the following command over the bus: V0XC1X. Both calibration constants will automatically be stored in E²PROM.
   E. Repeat steps A through D for the remaining DCA range using Table 6-8 as a guide.

Table 6-8. DC Current Calibration

199 DCA Range	199 Calibration Point	DC Current Calibrator Output	IEEE-488 Bus Commands
30mA	30.0000mA	30.0000mA	V30E–3XC0X
	00.0000mA	00.0000mA	V0XC1X
3 A	3.00000 A	3000.00mA	V3XC1X
	0.00000 A	0000.00mA	V0XC1X

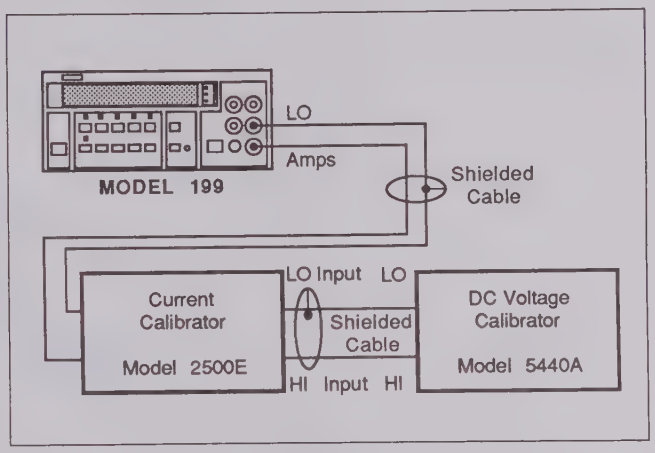


Figure 6-8. DC Current Calibration Configuration

6.4.12 TRMS AC Current Calibration

Perform the following procedure to calibrate the AC AMPS function:

NOTE

For front panel calibration, omit step 4 of the following procedure. For IEEE-488 bus calibration, omit step 3.

1. Select the AC AMPS function and the 30mA range.
2. Connect the AC current calibrator to the instrument as shown in Figure 6-9.
3. For front panel calibration, press SHIFT LOCAL, and proceed as follows:

A. With the 30.0000mA AC calibration point displayed on the Model 199, set the current calibrator to output 30.0000mA at a frequency of 500Hz.
B. After waiting sufficient time for the measurement to settle, press the NEXT button. The following message will be displayed for several seconds:

WORKING

C. With the 03.0000mA AC calibration point displayed, set the current calibrator to output 03.0000mA at 500Hz.
D. After allowing the measurement to settle, press the NEXT button. The following message will be displayed for several seconds:

WORKING

E. The instrument will exit the calibration program and return to the 30mA range.
F. Repeat the procedures in step 3 for the 3A AC range using Table 6-9 as a guide.

4. For IEEE-488 bus calibration, proceed as follows:
A. Set the current calibrator to output 30.0000mA at 500Hz.
B. After allowing sufficient time for the calibrator current to settle, send the following command over the bus: V30E-3XC0X.
C. Set the current calibrator to output 3.00000mA at 500Hz.
D. After allowing sufficient time for the calibrator current to settle, send the following command over the bus: V3E–3XC1X. Both calibration constants will automatically be stored in E²PROM.
E. Repeat steps A through D for the remaining ACA range using Table 6-9 as a guide.

NOTE

After completing the calibration procedure, place the unit in the "CAL LOCKED" state by pressing in on the CAL LOCK switch. Also, it is a good idea to place a dated calibration sticker over the switch access hole.

Table 6-9. TRMS AC Current Calibration

199 ACA Range	199 Calibration Point	Current Calibrator Output @ 500Hz	IEEE-488 Bus Commands
30mA	30.0000mA	30.0000mA	V30E–3XC0X
	03.0000mA	03.0000mA	V3E–3XC1X
3 A	3.00000 A	3000.00mA	V3XC0X
	0.30000 A	0300.00mA	V300E–3XC1X

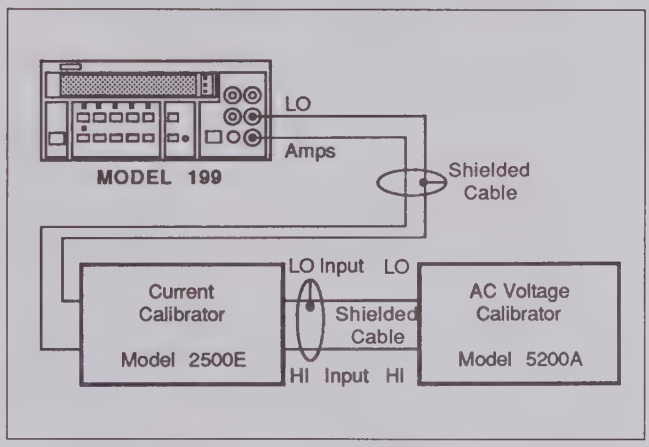


Figure 6-9. AC Current Calibration Configuration

6.5 DISASSEMBLY INSTRUCTIONS

If it becomes necessary to remove or replace a component, use the following general procedure to disassemble the unit, using Figures 6-10 and 6-11 as a guide. Note that the procedure should be carried out in the sequence given here, as each step depends on completion of the prior step. Reassemble the unit in the reverse order. For units not equipped with the optional Model 1992 Scanner, bypass step 2.

WARNING

To prevent a possible shock hazard, disconnect the line cord and all test leads from the Model 199 before beginning disassembly.

1. Case cover removal:
   A. Remove the two bottom screws that secure the case cover to the case sides.

NOTE

It is not necessary to remove the feet.

   B. Remove the screws that secure the rear bezel, then remove the bezel.
   C. Carefully slide the cover off the unit to the rear.
2. Scanner board removal (with option 1992):
   A. Pull out the quick-disconnect plugs from the rear.
   B. Remove the three screws that secure the scanner board to the analog board and rear panel.
   C. Grasp the board by the edges and gently pull it toward the front of the unit until it clears the rear and side of the case.
   D. Partially pull the board free of the unit to allow access to the ribbon cable plug underneath.
   E. Unplug the scanner board ribbon cable (P1), and remove the scanner board completely from the unit.
3. Digital board removal:
   A. Disconnect the trigger signal connector (P15) and display board ribbon cable (P14) from the digital board.
   B. Remove the screw that secures the digital board to the analog board standoff.
   C. Remove the two nuts that secure the IEEE-488 connector to the rear panel.
   D. Remove the four screws that secure the left grooved side panel, then remove the side panel.
   E. Pry the digital board free at connector P16 (at the end next to the power transformer) until it comes free of the connector pins, then remove the board from the unit.

WARNING

When removing or installing the digital board, be careful of the sharp points on the connector pins.

4. Front panel and display board removal:
   A. Disconnect the five wires going from the front panel input jacks to the analog board.
   B. Carefully pry the locking tabs free of the front panel rails, then remove the front panel.
   C. Remove the screws that secure the top and bottom rails to the right case sides, then remove the rails.
   D. Grasp the display board by the edges, and remove the board by pulling it forward until it is clear of the analog board tab.
5. Analog board removal.
   A. Remove the two screws that secure the rear panel to the case right side. As the screws are removed, remove case side.
   B. Remove the nut that secures the green ground wire to the rear panel.
   C. Disconnect the four rear panel input jack wires.
   D. Remove the two nuts that secure the AC receptacle to the rear panel, then remove the rear panel from the analog board.

WARNING

When reassembling the unit, the green ground wire must be securely connected to the rear panel to ensure continued protection against possible shock hazards.

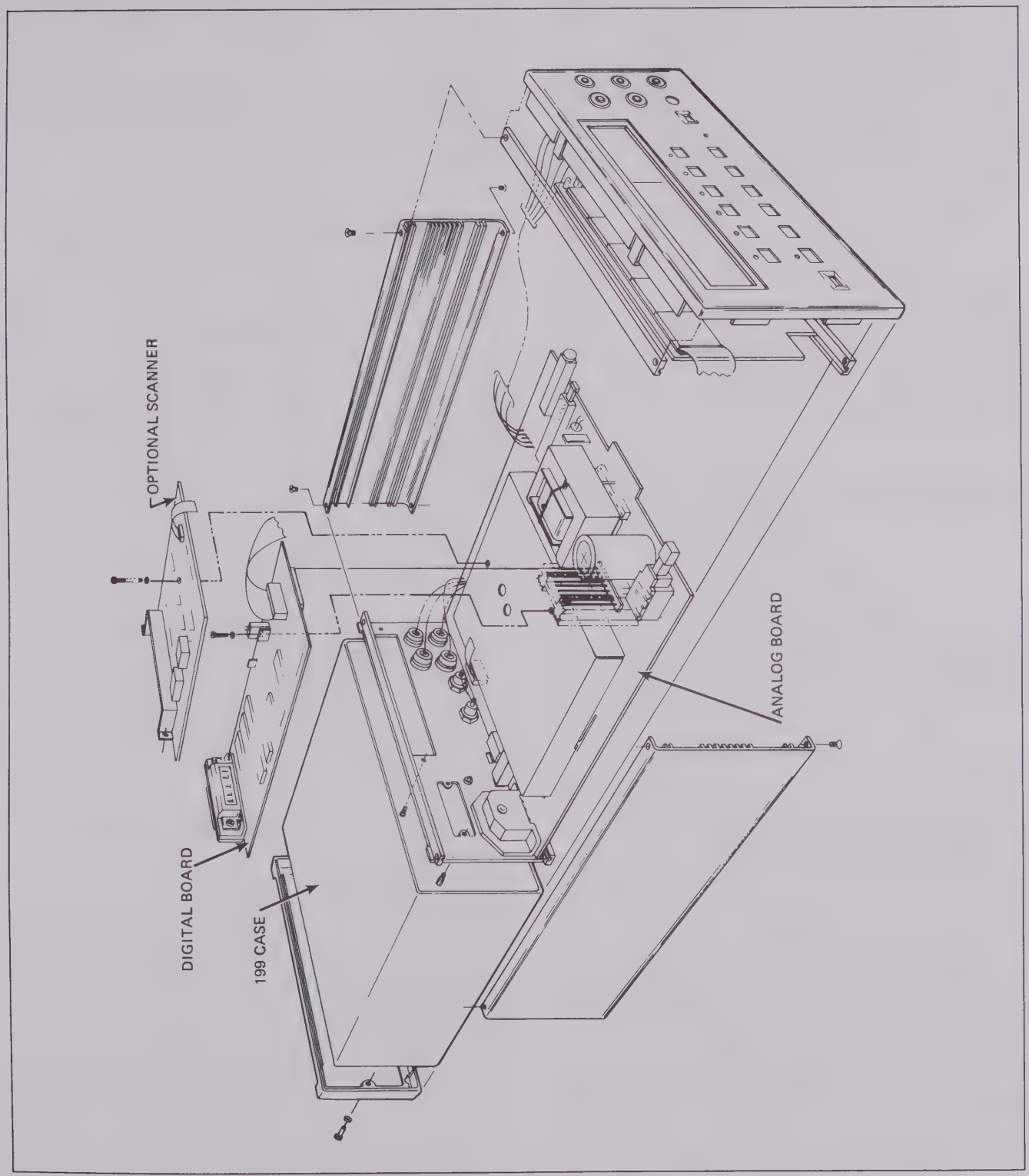


Figure 6-10. Model 199 Exploded View

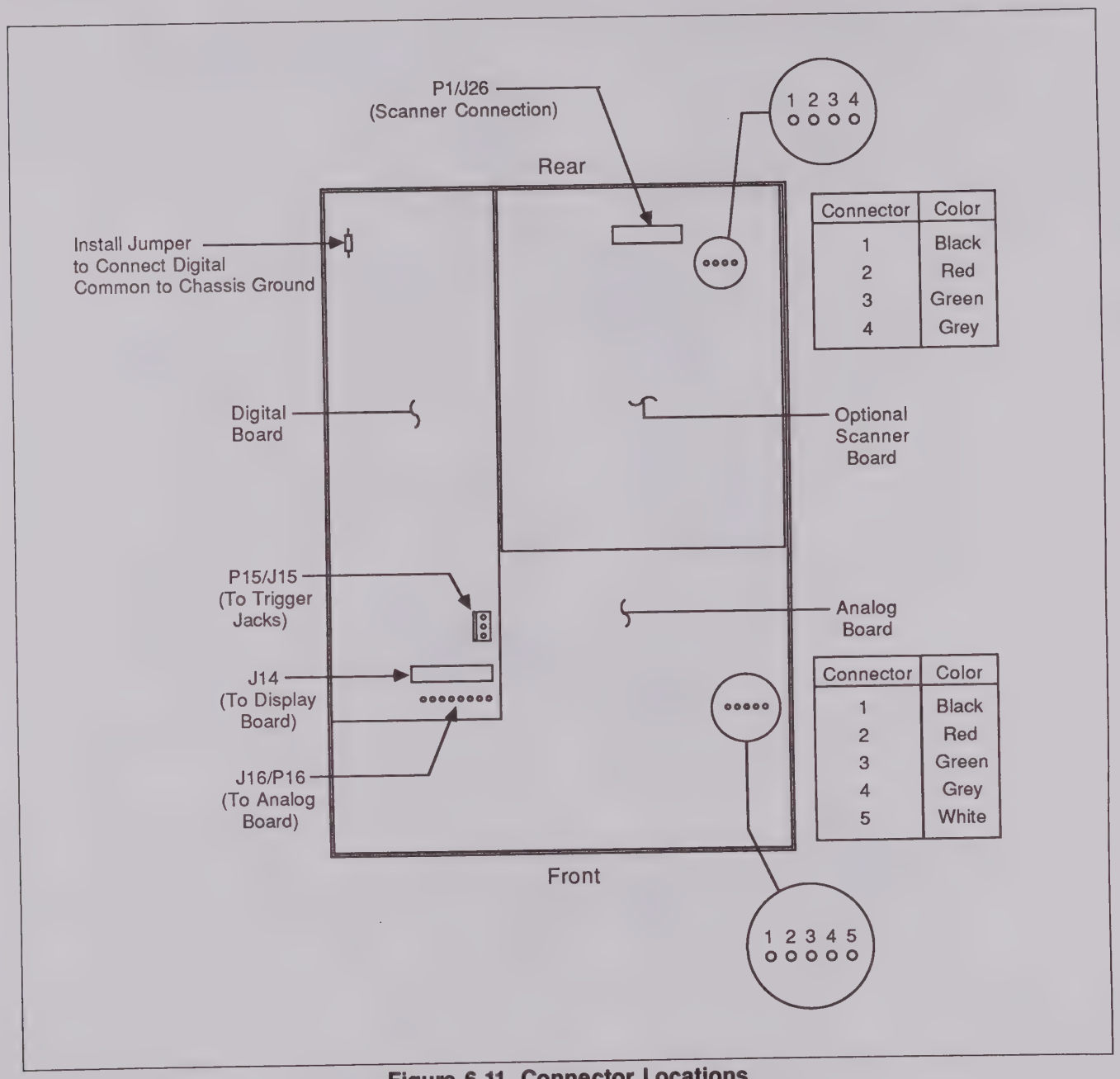


Figure 6-11. Connector Locations

6.6 SPECIAL HANDLING OF STATIC-SENSITIVE DEVICES

CMOS devices operate at very high impedance levels for low power consumption. As a result, any static charge that builds up on your person or clothing may be sufficient to destroy these devices, if they are not handled properly.

CAUTION
In order to avoid possible damage, assume that all devices are static sensitive.

When handling these devices, use the following precautions to avoid damaging them.

1. The devices listed in the replaceable parts list should be transported and handled only in containers specially designed to prevent static build-up. Typically, these parts will be received in anti-static containers of plastic or foam. Keep these devices in their original containers until ready for installation.
2. Remove the devices from their protective containers only at a properly grounded work station. Also ground yourself with a suitable wrist strap.
3. Handle the devices only by the body; do not touch the pins.
4. Any printed circuit board into which the devices is to be inserted must also be grounded to the bench or table.
5. Use only anti-static type solder suckers.
6. Use only grounded tip solder irons.
7. Once the device is installed on the PC board, it is normally adequately protected and normal handling can resume.

6.7 TROUBLESHOOTING

The troubleshooting information contained in this section is intended for use by qualified personnel having a basic understanding of analog and digital circuitry. The individual should also be experienced at using typical test equipment as well as ordinary troubleshooting procedures. The information presented here has been written to assist in isolating a defective circuit or circuit section. Isolation of the specific component is left to the technician. Note that schematic diagrams and component location drawings, which are an essential aid in troubleshooting, are located at the end of Section 7.

6.7.1 Recommended Test Equipment

Success in troubleshooting complex equipment like the Model 199 depends not only on the skill of the technician, but relies on the use of accurate, reliable test equipment. Table 6-10 lists the equipment recommended for troubleshooting the Model 199. Other equipment such as logic analyzers and capacitance meters could also be helpful, especially in difficult situations.

6.7.2 Power Up Self Test

Upon power up, the instrument will do a number of tests on itself. Tests are performed on memory (ROM, RAM and E²PROM). Whenever one of the memory tests fails, the instrument will lock up and must be repaired. If all the tests pass, then the frequency will be displayed. Immediately after turning on the Model 199, the following sequence will take place:

1. A digital check will be performed on the ROM circuitry. If the test fails, the instrument will lock up with the following message displayed:

   OOOOOOOOOO

   Replacing U4 may correct the problem.

2. If the ROM test passes, a digital self-test will then be performed on the RAM circuitry. If the RAM test fails, the instrument will lock up with the following error message displayed:

   AAAAAAAAAA

   Replacing U9 may solve the problem.
3. Finally, the E²PROM circuitry where the calibration constants, IEEE address and line frequency settings are stored will be checked. If this test fails, the following message displayed:

   UNCAL

   Pressing any front panel momentary button will return the instrument to normal operation however, a complete calibration will have to be performed, and the IEEE address and line frequency setting should be checked. If the test still fails after calibration, try replacing U20 before recalibrating the instrument again.
4. The instrument will then go to the power up default function.

Table 6-10. Recommended Troubleshooting Equipment

Equipment	Use
Five function DMM with 0.1% basic DCV accuracy, 10M input impedance	Power supply and DC voltage checks; analog signal tracing continuity, logic levels.
Dual-trace, triggered sweep oscilloscope, DC to 50MHz	Digital and analog waveform checks.
Digital frequency counter	Checking clock frequencies.

6.7.3 Diagnostics

Two programs available under DMM SETUP allow you to test the front panel LEDs, as well as perform the memory tests that are automatically performed upon power up. Also included is a troubleshooting test mode that is designed to turn on the various relays and switching FETs to allow signal tracing through the instrument. Perform the following steps in order to test the instrument.

1. Select the range and function to be tested for signal tracing.
2. Press SHIFT DMM SETUP then NEXT four times so that the instrument displays the following:

   LEDS OFF

3. Use uprange or downrange to select the following display:

   LEDS ON

4. Press NEXT to initiate the LED test.
5. While the LED test is running, observe the front panel LEDs and display segments to verify that all are functioning properly.
6. At the conclusion of the LED test, the instrument will display the following:

   DEBUG OFF

7. Press uprange or downrange to display the following:

   DEBUG ON

8. Press NEXT to enter the diagnostic test. The unit will display that the first N mode is selected as follows:

   N 01

9. Using Table 6-11, reference the selected N mode to the present range and function to determine which switching FETs and relays should be on. Apply an appropriate signal to the instrument, and trace the signal through the unit using the appropriate schematic as a guide.
10. To change the N mode, press the TRIGGER button.
11. To troubleshoot a different range or function, first exit the diagnostic program by pressing any front panel button except TRIGGER, then exit the setup mode by pressing NEXT to return to normal display. Change the range or function as required, then re-enter the diagnostic program by using DMM SETUP.

6.7.4 Power Supplies

Table 6-12 shows the various checks that can be made to the power supplies of the Model 199. In addition to the normal voltage checks, it is a good idea to check the various supplies with an oscilloscope for signs of noise or oscillations.

6.7.5 Signal Conditioning Checks

These circuits can be checked by using the diagnostic program (under DMM SETUP) as explained in the paragraph 6.7.3.

6.7.6 Digital and Display Circuitry Checks

The digital and display circuitry can be checked out by using the troubleshooting data found in Tables 6-13 and 6-14.

6.7.7 Scanner Checks

Troubleshoot the optional Model 1992 Scanner using Table 6-15.

Table 6-11. Model 199 Troubleshooting Mode

Function & Range	Measurement Phase	N Mode	Input Buffer Gain	Relays Closed	Range Switches Closed	Multiplex Switches Closed
300mV DC	SIG ZERO	01	X10	K1	Q11, U22A	Q34
	CAL ZERO	02	X1	K1	Q11, U22A	U25D, Q32
	CAL	03	X1	K1	Q11, U22A	U25C, Q32
	SIG	04	X10	K1	Q11, U22A	Q30
3V DC	SIG ZERO	01	X1	K1	Q11, U22A	Q34
	CAL ZERO	02	X1	K1	Q11, U22A	U25D, Q32
	CAl	03	X1	K1	Q11, U22A	U25C, Q32
	SIG	04	X1	K1	Q11, U22A	Q30
30V DC	SIG ZERO	01	X1	—	Q13, Q11, U22A	Q33
	CAL ZERO	02	X1	—	Q13, Q11, U22A	U25D, Q32
	CAL	03	X1	—	Q13, Q11, U22A	U25C, Q32
	SIG	04	X1	—	Q13, Q11, U22A	Q35
300V DC	SIG ZERO	01	X1	—	Q3, Q11, U22A	Q34
	CAL ZERO	02	X1	—	Q3, Q11, U22A	U25D, Q32
	CAL	03	X1	—	Q3, Q11, U22A	U25C, Q32
	SIG	04	X1	—	Q3, Q11, U22A	Q35
300mV AC	ZERO	01	X1	K4, K5	U23A, U23B	U25D, Q32
	CAL	02	X1	K4, K5	U23A, U23B	U25C, Q32
	SIG	03	X1	K4, K5	U23A, U23B	U25A, Q32
	No Test	04	—	—	—	—
3V AC	ZERO	01	X1	K4, K5	U21C	U25D, Q32
	CAL	02	X1	K4, K5	U21C	U25C, Q32
	SIG	03	X1	K4, K5	U21C	U25A, Q32
	No Test	04	—	—	—	—
30V AC	ZERO	01	X1	K4	U21B	U25D, Q32
	CAL	02	X1	K4	U21B	U25C, Q32
	SIG	03	X1	K4	U21B	U25A, Q32
	No Test	04	—	—	—	—
300V AC	ZERO	01	X1	K4	U23C, U21B	U25D, Q32
	CAL	02	X1	K4	U23C, U21B	U25C, Q32
	SIG	03	X1	K4	U23C, U21B	U25A, Q32
	No Test	04	—	—	—	—
300Ω	SENSE LO	01	X10	K2, K3	Q11, U22D, U24D	U24B, Q32
	REF HI	02	X1	K2, K3	Q11, U22D, U24D	Q35, Q12
	REF LO	03	X1	K2, K3	Q11, U22D, U24D	U25A, Q32
	SENSE HI	04	X10	K2, K3	Q11, U22D, U24D	Q30
3k	SENSE LO	01	X1	K2, K3	Q11, U22D, U24D	U24B, Q32
	REF HI	02	X1	K2, K3	Q11, U22D, U24D	Q35, Q12
	REF LO	03	X1	K2, K3	Q11, U22D, U24D	U24A, Q32
	SENSE HI	04	X1	K2, K3	Q11, U22D, U24D	Q30

Table 6-11. Model 199 Troubleshooting Mode (Cont.)

Function & Range	Measurement Phase	N Mode	Input Buffer Gain	Relays Closed	Range Switches Closed	Multiplex Switches Closed
30k	SENSE LO	01	X1	K2, K3	Q11, U22C, U24C	U24B, Q32
	REF HI	02	X1	K2, K3	Q11, U22C, U24C	Q35, Q12
	REF LO	03	X1	K2, K3	Q11, U22C, U24C	U24A, Q32
	SENSE HI	04	X1	K2, K3	Q11, U22C, U24C	Q30
300K	SENSE LO	01	X1	K2, K3	Q12, Q3, U22C, U24C	U24B, Q32
	REF HI	02	X1	K2, K3	Q12, Q3, U22C, U24C	Q35
	REF LO	03	X1	K2, K3	Q12, Q3, U22C, U24C	Q34
	SENSE HI	04	X1	K2, K3	Q12, Q3, U22C, U24C	Q30
3M	SENSE LO	01	X1	K2, K3	Q12, Q13, U22C, U24C	U24B, Q32
	REF HI	02	X1	K2, K3	Q12, Q13, U22C, U24C	Q35
	REF LO	03	X1	K2, K3	Q12, Q13, U22C, U24C	Q34
	SENSE HI	04	X1	K2, K3	Q12, Q13, U22C, U24C	Q30
30M	SENSE LO	01	X1	K2	Q12, U22C, U24C	U24B, Q32
	REF HI	02	X1	K2	Q12, U22C, U24C	Q35
	SENSE HI	03	X1	K2	Q12, U22C, U24C	Q30
	No Test	04	—	—	—	—
300M	SENSE LO	01	X1	K2	Q12, U22C, U24C	U24B, Q32
	REF HI	02	X1	K2	Q12, U22C, U24C	Q35
	SENSE HI	03	X1	K2	Q12, U22C, U24C	Q30
	No Test	04	—	—	—	—
30mA DC	SIG ZERO	01	X10	—	U23C	U25D, Q32
	CAL ZERO	02	X1	—	U23C	U25D, Q32
	CAL	03	X1	—	U23C	U25C, Q32
	SIG	04	X10	—	U23C	U22B, Q32
3A DC	SIG ZERO	01	X10	—	Q26, Q36, Q37	U25D, Q32
	CAL ZERO	02	X1	—	Q26, Q36, Q37	U25D, Q32
	CAL	03	X1	—	Q26, Q36, Q37	U25C, Q32
	SIG	04	X10	—	Q26, Q36, Q37	U22B, Q32
30mA AC	ZERO	01	X1	—	U23D, U23B, U23C	U25D, Q32
	CAL	02	X1	—	U23D, U23B, U23C	U25C, Q32
	SIG	03	X1	—	U23D, U23B, U23C	U22C, Q32
	No Test	04	—	—	—	—
3A AC	ZERO	01	X1	—	Q26,Q36,Q37,U23C,U23D,U23B	U25D, Q32
	CAL	02	X1	—	Q26,Q36,Q37,U23C,U23D,U23B	U25C, Q32
	SIG	03	X1	—	Q26,Q36,Q37,U23C,U23D,U23B	U22C, Q32
	No Test	04	—	—	—	—

Table 6-12. Power Supply Checks

Step	Item/Component	Required Condition	Remarks
1	S3 Line Switch	Set to 115 or 230V as required.	Line voltage selection
2	F2 Line Fuse	Check for continuity.	Remove fuse to check
3	Line Power	Plugged into live receptacle; power on.	
4	+5V Digital Supply U53, pin 3	+5V, ±5%	Referenced to digital common
5	+5V Analog Supply U51, pin 3	+5V, ±5%	Reference to analog common
6	±15V Analog Supplies U52, pin 3; U50, pin 3	+15V, −15V, ±0.75V	Referenced to analog common

Table 6-13. Digital Circuitry Checks

Step	Item/Component	Required Condition	Remarks
1	U4, U9, U20	Pass RAM, ROM and E²PROM self-test on power up.	Display will lock if failure occurs
2	U8, pin 2 (PA0)	TTL level pulses every 1msec	VIA clock
3	U8, pin 3 (PA1)	TTL level pulses every 15msec	Data
4	U8, pin 6 (PA4)	Switch data (+5V or 0V)	Data input to VIA when button pressed
5	U8, pin 7 (PA5)	Switch data (+5V or 0V)	Data input to VIA when button pressed
6	U8, pin 8 (PA6)	Switch data (+5V or 0V)	Data input to VIA when button pressed
7	U8, pin 9 (PA7)	Switch data (+5V or 0V)	Data input to VIA when button pressed
8	U8, pin 19	Variable pulse train (0V to +5V)	VIA Data Line
9	U14, pin 4	Variable pulse train (0V to +5V)	Data output
10	U3B, pin 13	Variable pulse train (0V to +5V)	A/D counts
11	U8, pins 12 through 16	Variable pulse train (0V to +5V)	Data to VIA from A/D
12	U10, pins 34 and 35	2MHz TTL	Bus Clock
13	U10, pin 37	+5V, ±5%	Reset line (goes low briefly on power up)
14	U5, pin 9	+5V signal pulsed 0V to +5V every 1msec	INT line
15	U5, pin 19	+5V (Logic "1")	RESET line
16	U5, pin 18	2MHz square wave at 0V to +5V	Clock
17	U5, pin 28	Should go true (+0V) when command is sent	ATN line
18	U5, 24 (NDAC), 25 (NRFD), 26 (DAV), and the data lines	Refer to Figure C-2 for required conditions	Handshake sequence

Table 6-14. Display Circuitry Checks

Step	Item/Component	Required Condition	Remarks
1	U4 and U5, pins 2, 9 and 14	+5V, ±5%	+5V supply
2	P14, pins 6, 11 through 24	Variable pulses	Segment drivers
3	U1, pins 6 and 16; U2, pins 4-7, 14-17	Variable pulses	Digit drivers
4	U5, pins 3, 4, 5, 6, 10, 11 and 12; U4, pins 1, 3, 4, 5	1msec negative going pulse every 10msec	
5	P14, pin 7 (S0)	Depress S1, S2, S3, or S4 button	Pulse present when button pressed
6	P14, pin 5 (S1)	Depress S5, S6, S7, or S8 button	Pulse present when button pressed
7	P14, pin 3 (S2)	Depress S9, S10, S11, S12, or S13 button	Pulse present when button pressed

Table 6-15. Scanner Board Checks

Step	Item/Component	Required Condition	Remarks
1	P1, pins 2 and 4	+5V, ±5%	All signals referenced to analog ground (P1, pins 1 and 2)
2	U1, pin 5	Stays high ½ second on power up, then goes LO.	Power-on safe guard.
3	U2, pin 2	Negative-going pulses	Control CLOCK
4	U2, pin 3	Positive-going pulses	Control DATA
5	U2, pin 7	Positive-going pulses	Control STROBE
6	U2, pins 11-18	On relay output LO, all others HI	Close selected channel using SCANNER button
7	K1-K8	Contact resistance <500mΩ	Check HI and LO for each relay; close relay with SCANNER button.

6.8 SCANNER INSTALLATION AND CHECKOUT

The following paragraphs discuss installation of the Model 1992 Scanner and Scanner checkout procedures. Refer to paragraph 2.11 for front panel scanner operation; IEEE-488 control of the scanner is located in paragraph 3.12.

6.8.1 Installation

Using Figure 6-12 and 6-13, install the Model 1992 Scanner as discussed below:

WARNING
Disconnect the line cord and all test leads from the Model 199 before removing the case cover.

1. Remove the two screws that secure the rear bezel, then remove the bezel.
2. Remove the screws that secure the case cover to the case sides, then slide the cover off the instrument to the rear.
3. Remove the two screws that secure the cover plate to the rear panel, then remove the cover plate. Save the screws, which will be used secure the scanner card to the rear panel.

WARNING
The cover plate must be installed if the scanner card is removed.

4. Remove the two quick-disconnect terminal blocks from the scanner card before installation.
5. Orient the scanner card above its final location (see Figure 6-12), and plug the ribbon cable (P1) into the mating receptacle (J26) on the analog board (see Figure 6-13). The red mark on the ribbon cable must be oriented on the right as viewed from the front of the unit.
6. Put the scanner card into the unit so that it lines up with the rear panel slot and is adjacent to the grooves in the case side.
7. Secure the scanner card to the rear panel with the two screws removed in step 2.
8. Secure the scanner card to the analog board using the supplied #6-32 × 1-1/8" screw.

WARNING
The screws must be installed to ensure proper grounding. The analog board shield must not be removed.

9. Using a pair of diagonal cutters, cut jumper W3 on the digital board (see Figure 6-13 for location). This step is necessary to enable scanner card operation.
10. Replace the case cover and bezel, and secure them with the screws removed earlier. Proceed to the following paragraph to check out the scanner card to verify that it is operational.

6.8.2 Card Checkout

Use the procedure below to test the functionality of the Model 1992 after installation.

1. Connect a short jumper wire between the H and L terminals of each channel input on the two terminal blocks.
2. Connect the A and B outputs together (H to H, L to L), and then connect the outputs to the VOLTS OHMS HI and LO terminals on the rear panel (H to HI, L to LO). Use the supplied output cables.
3. Plug the connecting blocks into the scanner card, and make sure the front panel INPUT switch is in the rear position.
4. Plug in the Model 199 and turn on the power.
5. Press the SCANNER button, and verify that the following message is displayed:

CHANNEL?

6. If, instead, the unit displays the "NO SCANNER" message, you may have forgotten to cut jumper W3 as described in paragraph 6.8.1.
7. Press 0 to return to normal display.
8. Select the following Model 199 operating modes.
   Function: OHMS
   Range: 300Ω
   Resolution: 5½ digits.
   Filter: off
   Zero: off
9. Temporarily short the rear panel VOLTS OHMS terminals, then press ZERO. Leave zero enabled for the remainder of the checkout procedure.
10. Press SHIFT TRIG SETUP, and use uprange or downrange so that the "ONE SHOT" trigger mode message is displayed.
11. Press NEXT twice to return to normal display.
12. Press SHIFT SCAN SETUP, then NEXT twice to display the present scan mode. Use uprange or downrange to display the following:

STEP

13. Press NEXT to complete programming.
14. Press SCANNER and note that the instrument displays the following:

LIMIT?

15. Press 8 to program the limit.
16. Press TRIGGER to close channel 1. The instrument will display the resistance reading on channel 1.
17. Verify the resistance reading is less than 1Ω.
18. Press TRIGGER to cycle to the next channel. Verify that the resistance reading is less than 1Ω.
19. Repeat step 18 for the remaining channels.
20. If all channels show an overflow reading in its test, it is probable that the card was installed improperly (refer to paragraph 6.8.1). If only one channel measures improperly, check to see that the channel jumper is installed properly.

21. Turn off the instrument power, and unplug the connecting blocks. Remove the shorting jumpers from the channel inputs. Assuming the scanner card functioned normally, the unit is now reading for use.

6.8.3 Relay Shield Jumper

A jumper (W1), on the scanner board, is factory installed to connect the relay shields to analog ground (see Figure 6-13). If desired, this jumper can be cut to float the shields, or to connect another potential (for example, for guarding).

CAUTION
Maximum voltage between shields and contact is 250V DC.

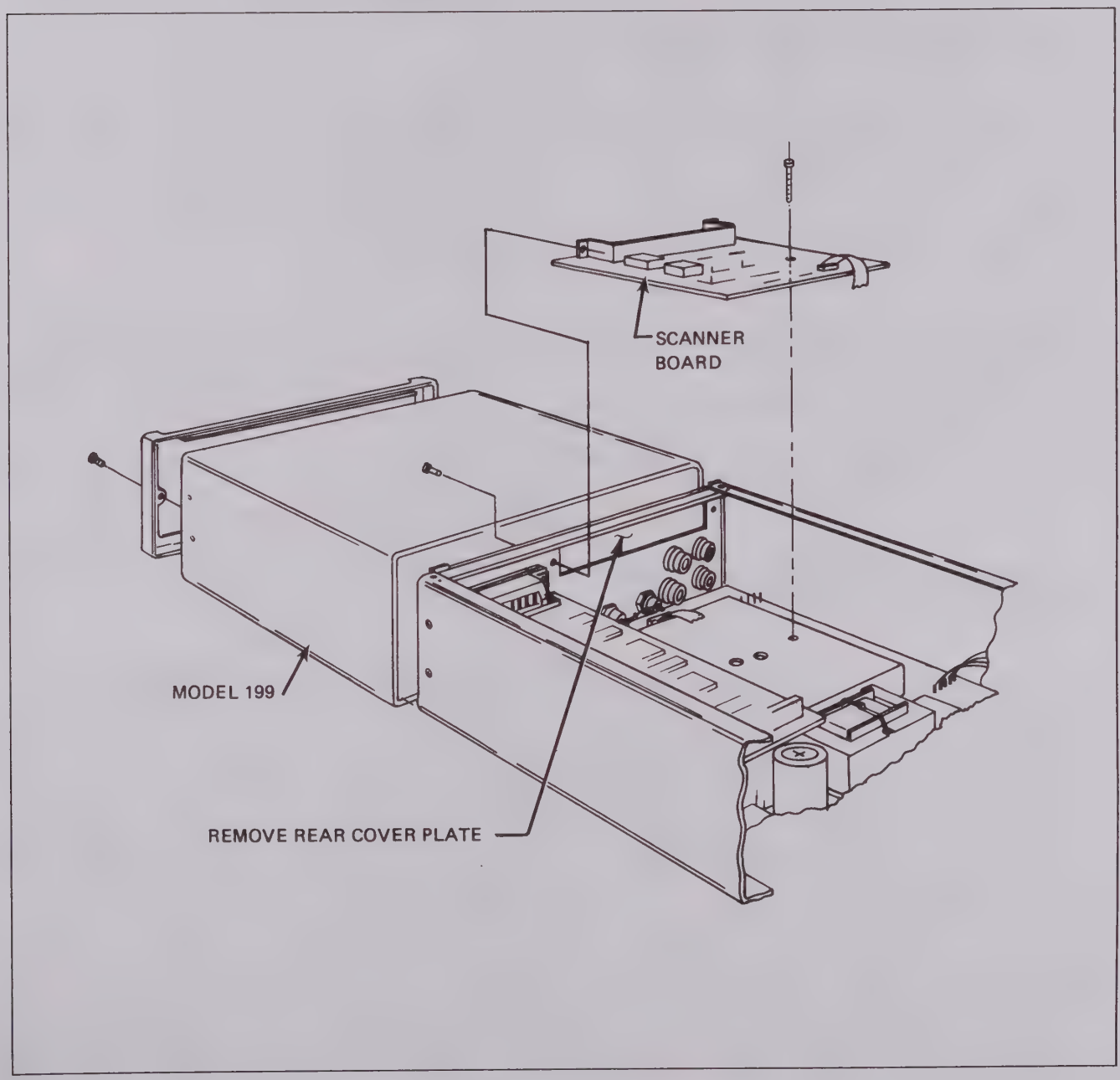


Figure 6-12. Scanner Installation

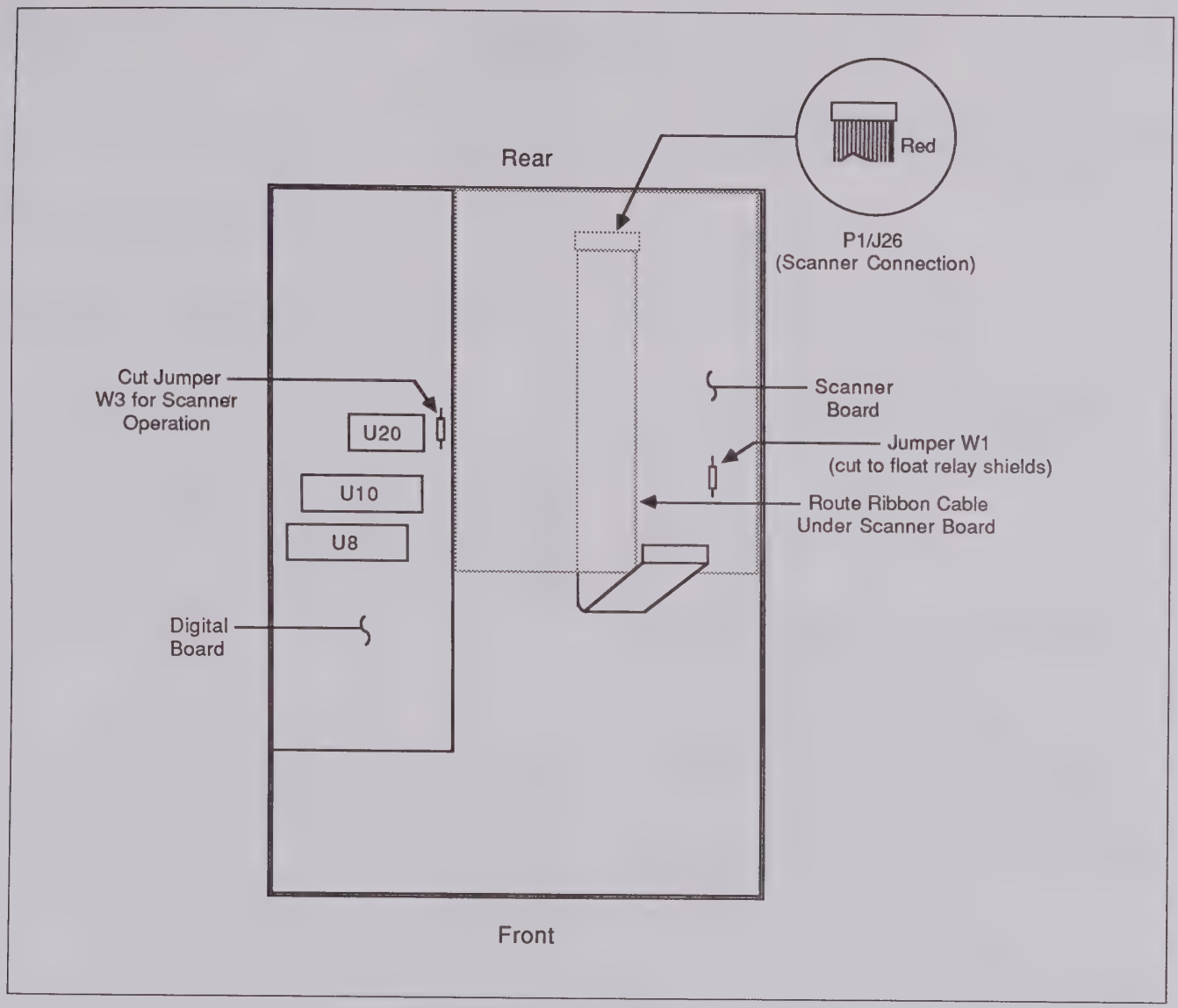


Figure 6-13. Scanner Connector Location

SECTION 7
Replaceable Parts

7.1 INTRODUCTION

This section contains replacement parts information, component location drawings and schematic diagrams for the Model 199.

7.2 PARTS LIST

Parts are listed alphanumerically in order of their circuit designations. Table 7-1 contains parts list information for the display board. Table 7-2 contains parts list information for the digital board. Table 7-3 contains parts list information for the analog board. Table 7-4 contains a miscellaneous parts list for the Model 199. Model 1992 parts are listed in Table 7-5.

7.3 ORDERING INFORMATION

To place an order, or to obtain information concerning replacement parts, contact your Keithley representative or the factory. See inside front cover for addresses. When ordering include the following information:

1. Instrument Model Number
2. Instrument Serial Number
3. Parts Description
4. Circuit Designation (if applicable)
5. Keithley Part Number

If an additional instruction manual is required, order the manual package (Keithley Part Number 199-901-00). The manual package contains an instruction manual and any applicable addenda.

7.4 FACTORY SERVICE

If the instrument is to be returned to the factory for service, please complete the service form which follows this section and return it with the instrument.

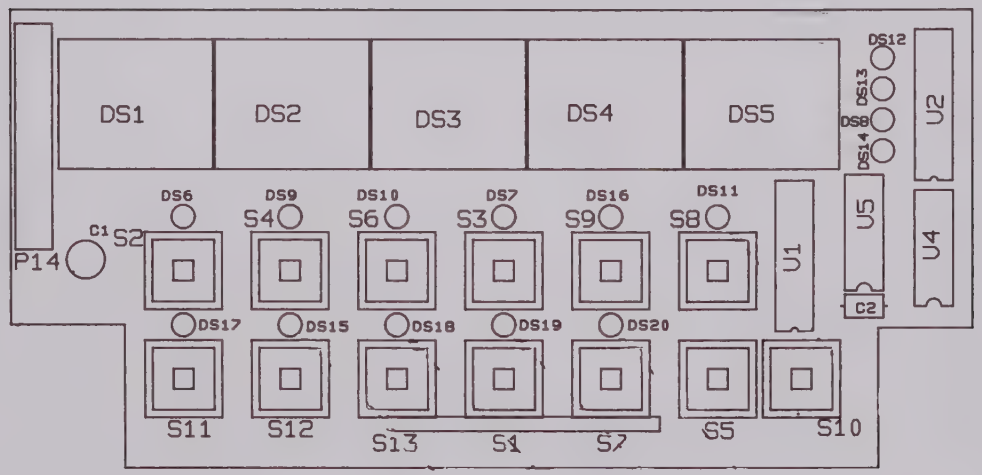
7.5 SCHEMATIC DIAGRAMS AND COMPONENT LOCATION DRAWINGS

Schematic diagrams and component location drawings follow the appropriate replaceable parts list for that particular board.

TABLE 7-1. DISPLAY BOARD, PARTS LIST

CIRCUIT DESIG.	DESCRIPTION	KEITHLEY PART NO.
	PILOT LIGHT,RED,LED DS6-DS10.DS12-DS14	PL-71
	PUSHBUTTON CAPS S1-S4,S6,S7,S9,S11228-317-5	
C2	CAP,.1uF,20%,50V,CERAMIC	C-365-.1
DS1..DS5	DISPLAY,DIGITAL (DOUBLE DIGIT)	DD-39
FOR PL-71'S	MOUNTING KIT	MK-22-3
P14	CABLE ASSEMBLY,26 CONDUCTOR	CA-27-4
S1..S13	SWITCH,MOMENTARY	SW-435
S5,S8	PUSHBUTTON CAPS	228-317-6
U1,U2	IC,SINK DRIVER,UND2596A	IC-578
U4,U5	IC,8 BIT PAR OUT SHIFT REG,74HCT164	IC-456

LTR.	ECO NO.	REVISION	ENG.	DATE
C	12296	RELEASED	S.Z.	10/12/87
D		REVISED		



NOTE:
INSTALL MK-22-3 UNDER DS6 THRU DS10,DS12, THRU DS14,DS16,DS17.

PUSHBUTTON SELECTION CHART

SCHEMATIC DESIGNATION	PART NUMBER
S1-S4,S6,S7,S9	228-317-5
S11-S13	228-317-5
S5,S8	228-317-6

Figure 7-1. Display Board, Component Location Drawing, Dwg. No. 199-110

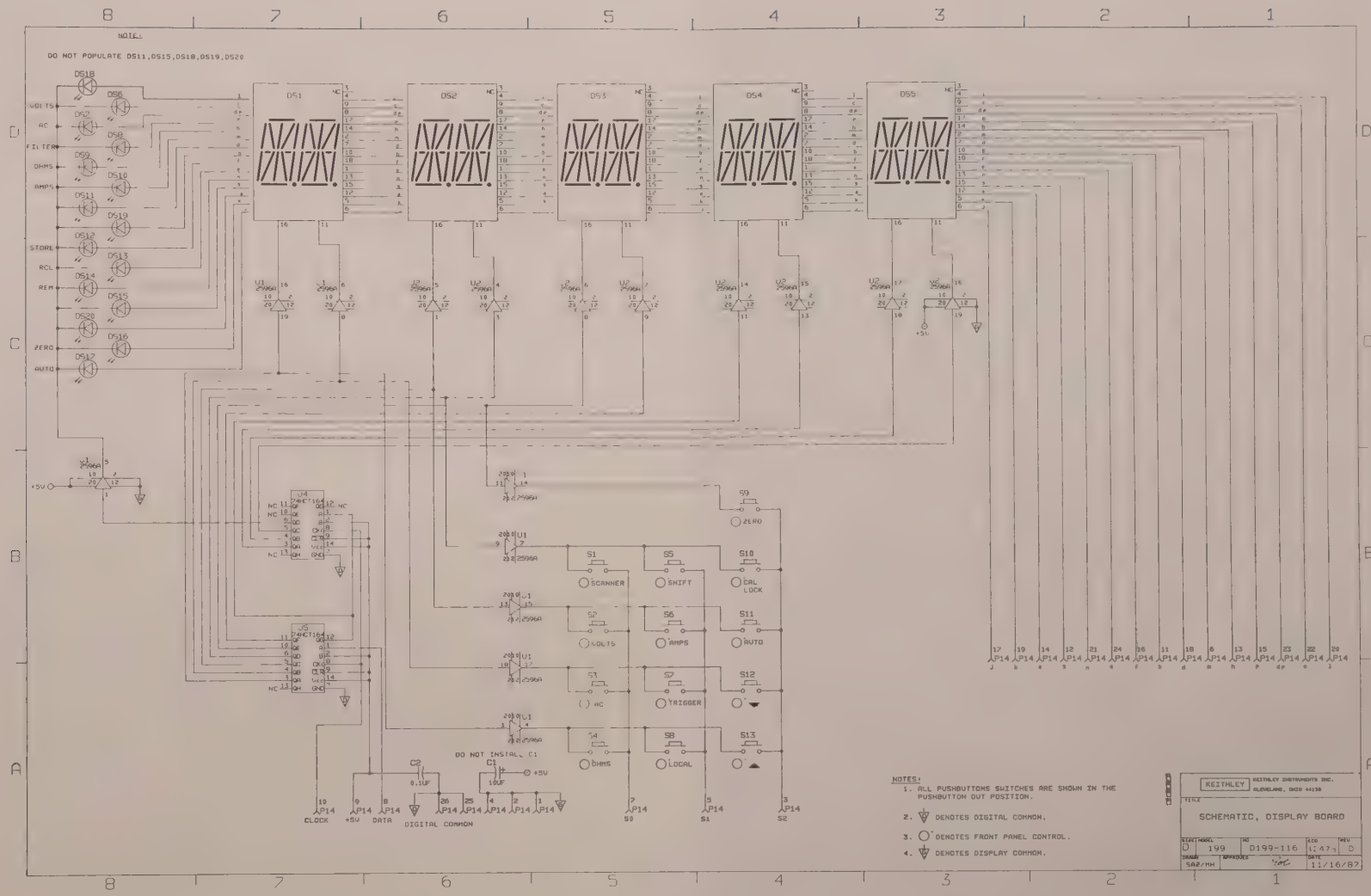


Figure 7-2. Display Board, Schematic Diagram, Dwg. No. 199-116

TABLE 7-2. DIGITAL BOARD, PARTS LIST

CIRCUIT DESIG.	DESCRIPTION	KEITHLEY PART No.
	#6-32x7/16 PHIP.PAN HD SCR	6-32x7/16PPH
	IEEE MOUNTING HARDWARE	CS-378
	STANDOFF	ST-151-13
	#4-40x5/16 PHIL.PAN HD SCR 4-40x5/16PPH FOR J7	
	SOCKET FOR U4	
C1,C3..C6,C8,C10,C16	CAP,.01uF,20%,50V,CERAMIC	C-365-.01
C11	CAP,22uF,-20+100%,25V,ALUM ELEC	C-314-22
C12,C13	CAP,15pF,10%,1000V,CERAMIC	C-64-15P
C14	CAP,.01uF,20%,500V,CERAMIC	C-22-.01
C2,C9	CAP,.1uF,20%,50V,CERAMIC	C-365-.1
CR1...CR6	DIODE,SILICON,1N4148 (D0-35)	RF-28
J14	CONN,DUAL 13-PIN-BERG	CS-389-3
J15	CONN,MALE,3 PIN	CS-288-3
J7	CONN,RIGHT ANGLE,24 PIN	CS-501
P16	CONN,FEMALE,8 PIN,BTM MNT	CS-618-8
R1,R2	RES,100,5%,1/4W,COMPOSITION OR FILM	R-76-100
R10,R11	RES NET,82,5%,.25W	TF-141
R3	RES,38.3K,1%,1/8W,METAL FILM	R-88-38.3K
R4	RES,909K,1%,1/8W,METAL FILM	R-88-909K
R5	RES,9.09K,1%,1/8W,METAL FILM	R-88-9.09K
R6	RES,1M,5%,1/4W,COMPOSITION OR FILM	R-76-1M
R7	RES NET,3.3K,5%,1.25W	TF-140
R8	RES NET,3.3K,2%,.6W	TF-101
U1	IC,10 INPUT AND-OR-INVERT ARRAY,PAL10L8	IC-579
U10	IC,8 BIT MICROPROCESSING UNIT,68B09	LSI-65
U11,U12	IC,8 CHANNEL SOURCE DRIVER,UDN2585	IC-405
U13,U14	IC,HEX INVERTER,74HC04	IC-354
U15,U16	IC,OCTAL EDGE TRIG FLIP FLOP,74HCT374	IC-397
U17	IC,QUAD 2-INPUT NOR GATE 74AHCT02	IC-510
U2	IC,MICROPOWER BIPOLAR MONOLITHIC,6728	IC-177

U20	IC,PROGRAMMABLE E2ROM 2816A	LSI-83
U3	IC,DUAL 4 BIT COUNTER,74HCT393	IC-462
U4	IC,32Kx8 EPROM,27C256	LSI-85
U5	IC,GPIB ADAPTER,9914A	LSI-49
U6	IC,OCTAL INTERFACE BUS,75160	IC-298
U7	IC,OCTAL INTERFACE BUS TRANSCEIVER,75161	IC-299
U8	IC,VERSATILE INTERFACE ADAPTER,G65SC22	LSI-86
U9	IC,(8KX8) HI SPEED STATIC CMOS RAM,6264	LSI-66
W3	JUMPER	J-15
Y1	CRYSTAL,8.0000MHZ	CR-24-1

LTR.	ECO NO.	REVISION	ENG. DATE
B	12296	RELEASED	10/12/87

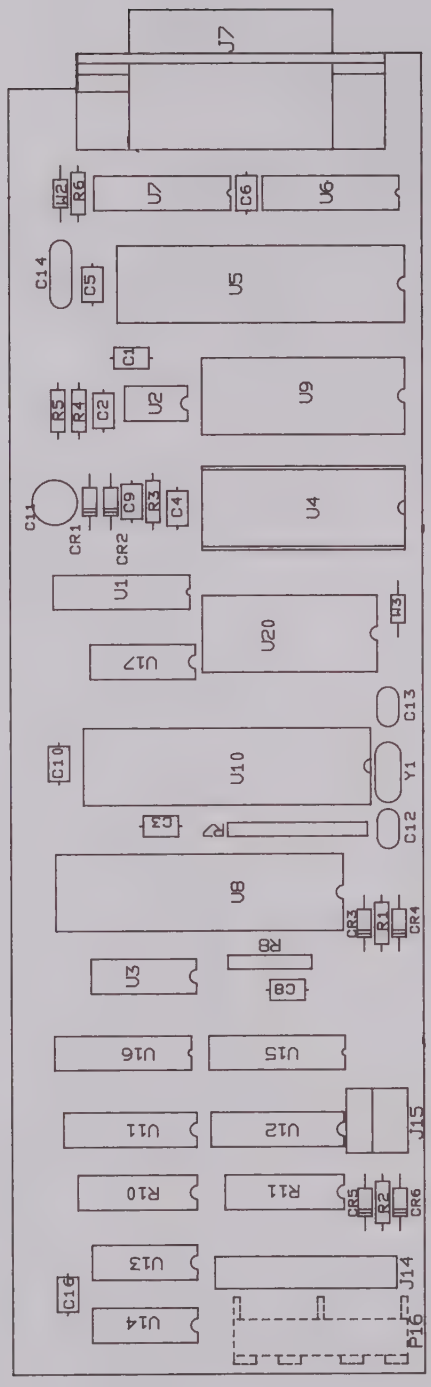


Figure 7-3. Digital Board, Component Location Drawing, Dwg. No. 199-100

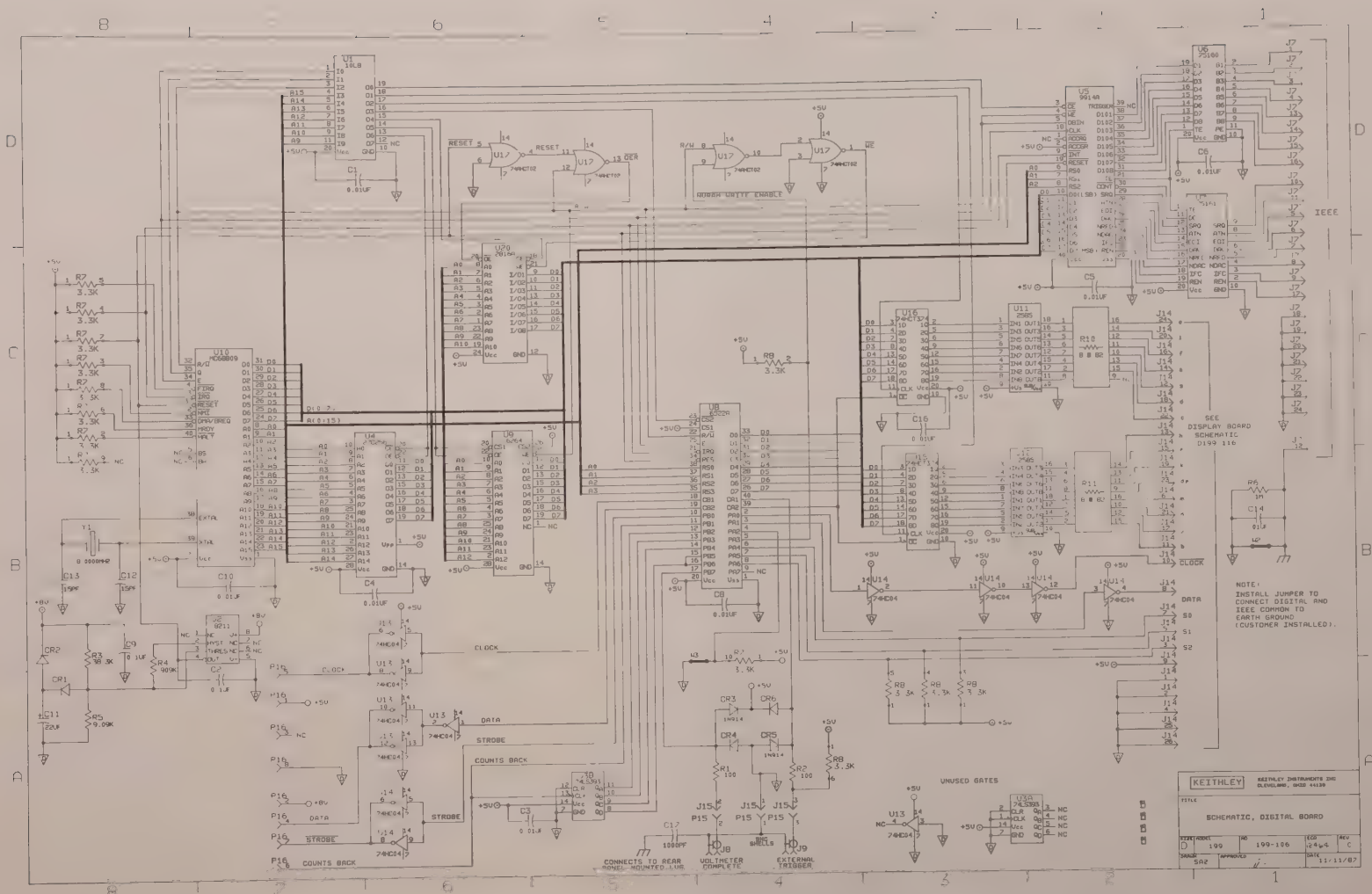


Figure 7-4. Digital Board, Schematic Diagram, Dwg. No. 199-106

TABLE 7-3. ANALOG BOARD, PARTS LIS

CIRCUIT DESIG.	DESCRIPTION	KEITHLEY PART NO.
	#4-40 PEM NUT	FA-131
	#6-32 PEM NUT	FA-135
	ANALOG SHIELD,UPPER	C199-312
	FUSE CARRIER	FH-25
	FUSE HOLDER	FH-21
	HEAT SINK	HS-25
	JUMPER	J-15
	STANDOFF	ST-129
	ANALOG SHIELD,LOWER	B199-313
	PUSHBUTTON,BROWN	C29465-2
	PUSHBUTTON,RED	C29465-3
AT1	IC,DUAL CMR HIGH SPEED OPT0,HCPL-2631	IC-588
AT2	IC,OPTOCOUPLER,2601	IC-239
AT3	IC,OPTOCOUPLER,TIL117	IC-362
C15..C17,C22,C27,C61,C66		
C2,C3,C6,C9,C14,	CAP,.1uF,20%,50V,CERAMIC	C-365-.1
C31	CAP,150pF,5%,100V,CERAMIC	C-372-150P
C32	CAP,.0047uF,10%,100V,POLYPROPYLENE	C-306-.0047
C33,C56..C58	CAP,10uF,-20+100%,25V,ALUM ELEC	C-314-10
C34,C35	CAP,33pF,10%,1000V,CERAMIC	C-64-33P
C36,C37	CAP,330pF,10%,1000V,CERAMIC	C-64-330P
C38	CAP,680pF,5%,500V,POLYSTYRENE	C-138-680P
C40	CAP,.1uF,10%,630V,POLYESTER	C-364-.1
C44	CAP,15uF,10%,20V,TANTALUM	C-204-15
C45	CAP,2uF,10%,100V,POLYESTER	C-294-2
C46	CAP,.47uF,20%,50V,POLYESTER	C-350-.47
C47	CAP,1uF,20%,50V,POLYESTER	C-350-1
C48	VAR CAP,2.5-6pF,500V	C-359
C49	CAP,7-70pF,500V,VARIABLE	C-345
C53	CAP,68pF,5%,500V,POLYSTYRENE	C-138-68P
C59	CAP,1500uF,-20+100%,25V,ALUM ELEC	C-314-1500
C60	CAP,47uF,-20+100%,25V,ALUM ELEC	C-314-47

C63,C65	CAP,680uF,-10+100%,35V,ELECTROLYTIC	C-309-680
C72	CAP,10,000uF,-20+30%,25V,ALUM ELEC	C-342-10,000
C73,C75,C76	CAP,22pF,10%,1000V,CERAMIC	C-64-22P
C74	CAP,820pF,10%,1000V,CERAMIC	C-64-820P
CR1..CR3,CR12,CR16	DIODE,DIFFUSED,1N4148	RF-28
CR13,CR14	DIODE,SILICON,W04M	RF-46
CR15	DIODE,BRIDGE,KBP02	RF-36
CR6	DIODE,BRIDGE,PE05	RF-48
CR7	DIODE,SILICON,1N4139	RF-34
CR8..CR11	DIODE,SWITCHING,1N4149	RF-60
F1	FUSE,3A,250V	FU-82
F2	FUSE,.18A,250V,3AG,SLO-BLO	FU-29
FOR U19	SOCKET,8 PIN	SO-72
FOR U27	SOCKET,14 PIN	SO-70
J16	CONN,MALE,8 PIN	CS-338-13
J17..J25	CONN,BRASS PIN	TE-110
J26	CONN,DUAL 5-PIN-BERG	CS-389-4
J6	CONN,AC RECEPTACLE	CS-388
K1,K2	RELAY, SPST (HIGH VOLTAGE)	RL-99
K3..K5	RELAY, SPST (HIGH VOLTAGE)	RL-70
Q1	TRANS,N-CHANNEL DUAL FET,MP841	TG-200
Q22	TRANS,NPN TRANS,GES5818	TG-138
Q26,Q36	TRANS,N CHANNEL FET,BUZ71	TG-196-600
Q3	SELECTION,TG-174	A199-
Q30,Q33,Q35	SELECTION,TG-139	A193-603
Q37	TRANS,N-CHANNEL MOSPOWER FET,2N7000	TG-195
Q4	TRANS,N-CHANNEL JFET,PN5434	TG-174
Q5,Q6,Q11..Q13,Q32,Q34	SELECTION,TG-128	A31841
Q7,Q8,Q17	TRANS,N-CHANNEL FET	TG-128
Q9,Q16	SELECTION,TG-138	A197-600
R1,R2,R45..R52	RES,1M,5%,1/4W,COMPOSITION OR FILM	R-76-1M
R12..R15	RES,100K,1%,1W,METAL FILM	R-344-100K
R17	RES NET,10M,1.111M,110.95K,10.101K	TF-214
R20	RES NET,100K,2%,2.25W	TF-177-3
R21	RES,100K,1%,1/8W,METAL FILM	R-88-100K
R23	RES,30K,1%,1/8W	R-348-30K
R24	RES,13K,.1%,1/10W,METAL FILM	R-263-13K
R25	RES,1M,1%,1/8W,METAL FILM	R-88-1M

R26	RES,2K,1%,1/8W	R-348-2K
R27	RES,1.002K,.1%,1/10W,METAL FILM	R-263-1.002K
R3	RES,1K,5%,1/4W,COMPOSITION OR FILM	R-76-1K
R30	RES,.1,.1%,7.5W,WIRE WOUND	R-262-.1
R31	RES,22M,10%,1/2W,FIXED-COMPOSITION	R-1-22M
R32	RES,118K,.1%,1/10W,METAL FILM	R-168-118K
R33	RES,1.17M,.25%,.75W,METAL FILM	R-352-1.17M
R34	RES,20K,5%,6.5W,WIRE WOUND	R-336-20K
R35	RES,9.09K,.1%,1/10W,METAL FILM	R-263-9.09K
R54	RES,32.4K,1%,1/8W,METAL FILM	R-88-32.4K
R55,R56	RES,20K,.1%,1/10W,METAL FILM	R-263-20K
R57	RES,*,1%,1/8W,METAL FILM	R-88-*
R58	RES,15.8K,1%,1/8W,METAL FILM	R-88-15.8K
R59	RES,7.87K,1%,1/8W,METAL FILM	R-88-7.87K
R6	RES,142.8K,.1%,1/8W	R-176-142.8K
R60	RES,560K,5%,1/4W,COMPOSITION OR FILM	R-76-560K
R61	RES,18.2K,1%,1/8W,METAL FILM	R-88-18.2K
R62	RES,8.25K,1%,1/8W,METAL FILM	R-88-8.25K
R63	RES,2K,5%,1/4W,COMPOSITION OR FILM	R-76-2K
R64	RES,1K,1%,1/8W,METAL FILM	R-348-1K
R66	RES,1.33K,.1%,1/10W,METAL FILM	R-263-1.33K
R67	RES,11K,.1%,1/10W,METAL FILM	R-263-11K
R68(18.6K	RES,MATCHED SET	R-363
R69(15K)		
R7	RES,996K,.1%,1/4W,METAL FILM	R-264-996K
R70	RES,6.19K,.1%,1/10W,METAL FILM	R-263-6.19K
R71	RES,9K,1%,1/8W,METAL FILM	R-348-9K
R72	RES,15K,1%,1/8W,METAL FILM	R-88-15K
R73	RES,14K,1%,1/8W,METAL FILM	R-88-14K
R75	RES,10,.5%,1/8W,METAL FILM	R-246-10
R76	RES,12.4K,1%,1/8W,METAL FILM	R-88-12.4K
R77	RES,9.76K,1%,1/8W,METAL FILM	R-88-9.76K
R79	RES,220,5%,1/4W,COMPOSITION OR FILM	R-76-220
R8	RES,7.78K,.1%,1/8W	R-176-7.78K
R80	RES,162K,1%,1/8W,METAL FILM	R-88-162K
R81	RES,7.5K,5%,1/4W,COMPOSITION OR FILM	R-76-7.5K
R82,R85,R86	RES,270,5%,1/4W,COMPOSITION OR FILM	R-76-270
R83,R84	RES,360,5%,1/4W,COMPOSITION OR FILM	R-76-360

R87	RES,470,5%,1/4W,COMPOSITION OR FILM	R-76-470
R88	RES,10K,5%,1/4W,COMPOSITION OR FILM	R-76-10K
R89..R95	RES,100K,5%,1/4W,COMPOSITION OR FILM	R-76-100K
R9	RES NET,10K,2%,.25W	TF-39
R96	RES,200,5%,1/4W,COMPOSITION OR FILM	R-76-200
RT1	THERMISTER,250mSEC,500V	RT-9-2
S1	SWITCH, PUSHBUTTON	SW-468
S2	SWITCH,PUSHBUTTON (6 POLE)	SW-466
S3	SWITCH,SLIDE (DPDT)	SW-318
T1	TRANSFORMER, (90-110V, 180-220V)	TR-259
T1	TRANSFORMER (105-125V, 210-250V)	TR-258
TE1,TE2	TERMINAL	TE-97-1
U11,U13,U19	IC,22V OP-AMP,NE5534N	IC-540
U16	SELECTED,IC-283	31847-1
U17	IC,DUAL 4-BIT DEC./BIN. COUNT.,74HC390	IC-500
U18	IC,DUAL 4-BIT COUNTER,74HCT393	IC-462
U2,U4,U5,U42	IC,LOW PWR/OFFSET VOLT. QUAD COMP,LM339	IC-219
U20	SELECTION,IC-325	A196-601
U21..U25	IC,CMOS ANALOG SWITCH,DG211	IC-320
U26	IC,18V OP-AMP,LF353N	IC-246
U27	IC,TRMS TO DC CONVERTER,637JD	IC-352
U28	IC,DUAL JFET INPUT OP AMP,LF412	IC-504
U29..U32	IC,8-STAGE SHIFT/STR REGIST.,MC14094BCP	IC-251
U33	IC,DARLINGTON TRANS ARRAY,ULN20003A	IC-206
U43	IC,QUAD 2-INPUT OR GATES,74HC02	IC-412
U44,U45	IC,TRIP.2-CHAN. MULTIPL/DEMUX.,CD4053BC	IC-283
U46	SELECTION,IC-165	A30167
U49	IC,HEX INVERTER,74HCT04	IC-444
U50	IC,NEG VOLTAGE REG -15V,500mA,79M15	IC-195
U51	IC,+5V VOLTAGE REGULATOR,7805	IC-93
U52	IC,POS VOLTAGE REG +15V,500mA,78M15	IC-194
U53	HEAT SINK,ASS'Y	A32469-4
U6	IC,QUAD 2-INPUT NAND,74HC00	IC-351
U7,U8	IC,DUAL D-TYPE FLIP-FLOP,74HC74	IC-337
VR1	DIODE,ZENER 4.3V,1N5991B	DZ-81
VR2	DIODE,ZENER 6.4V,1N4579	DZ-73
Y1	CRYSTAL,3.84MHz	CR-13

LTR.	ECO NO.	REVISION	ENG.	DATE
B	12296	RELEASED	S2	10/12/87
C	12481	REVISED		11/23/87

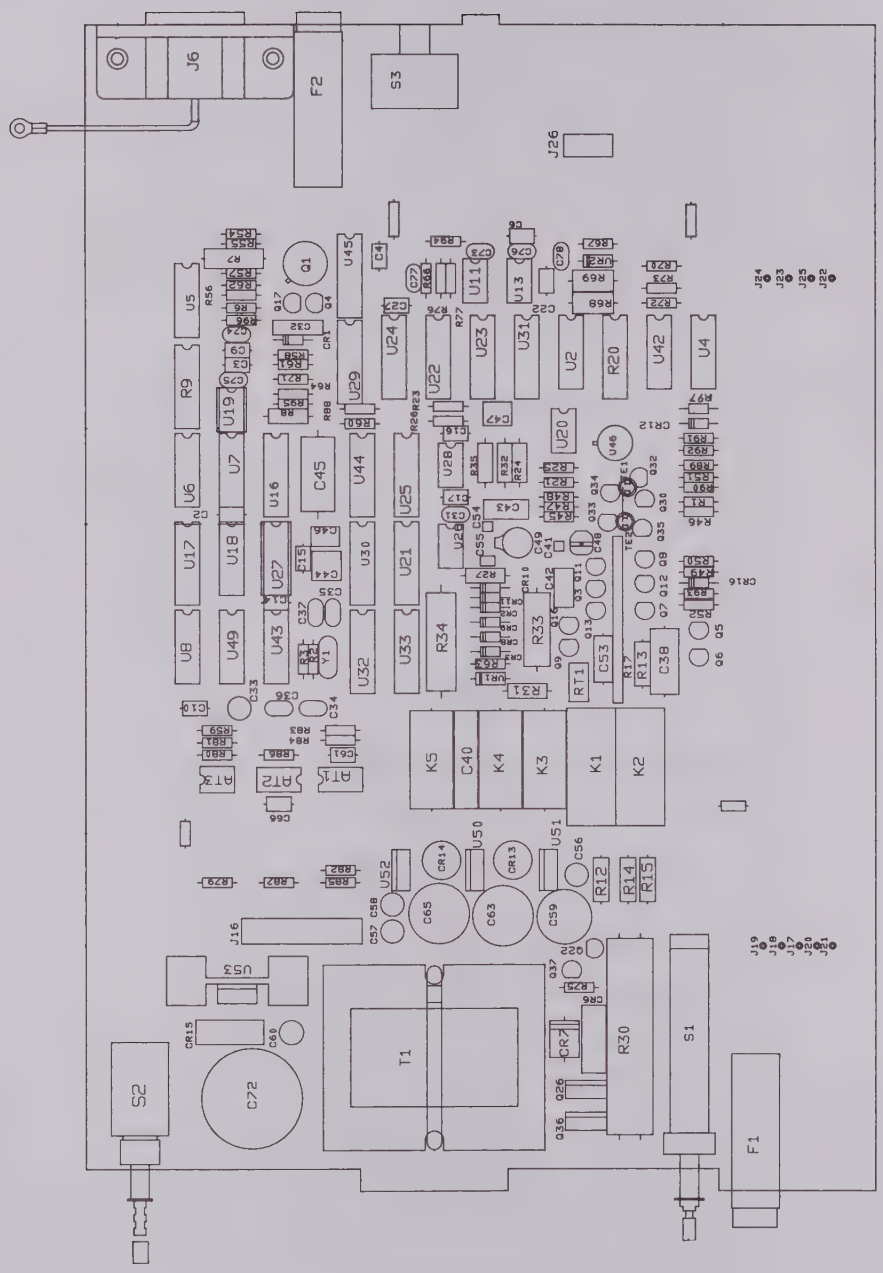


Figure 7-5. Analog Board, Component Location Drawing, Dwg. No. 199-120

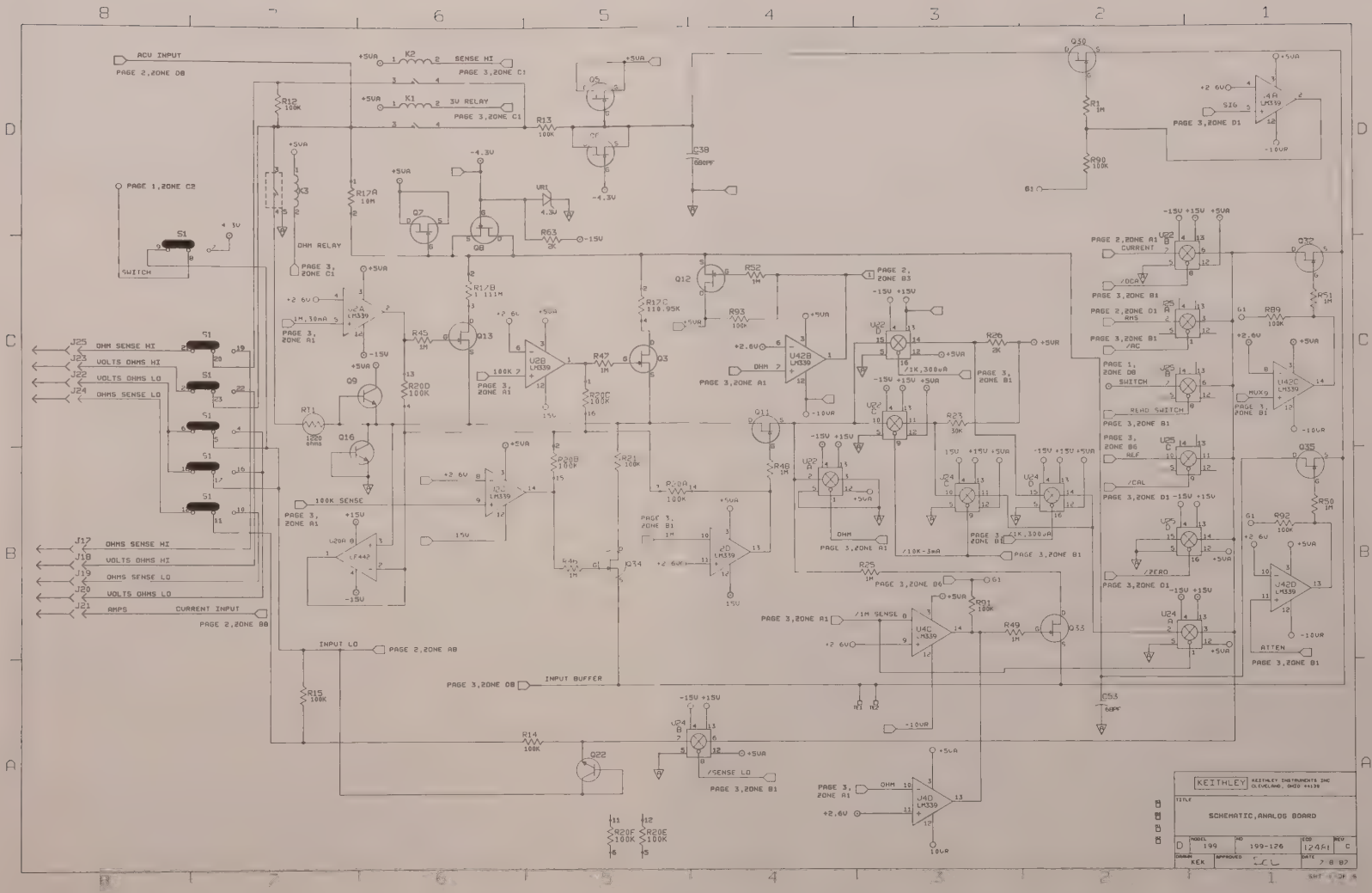


Figure 7-6. Analog Board, Schematic Diagram, Dwg. No. 199-126 (sheet 1 of 5)

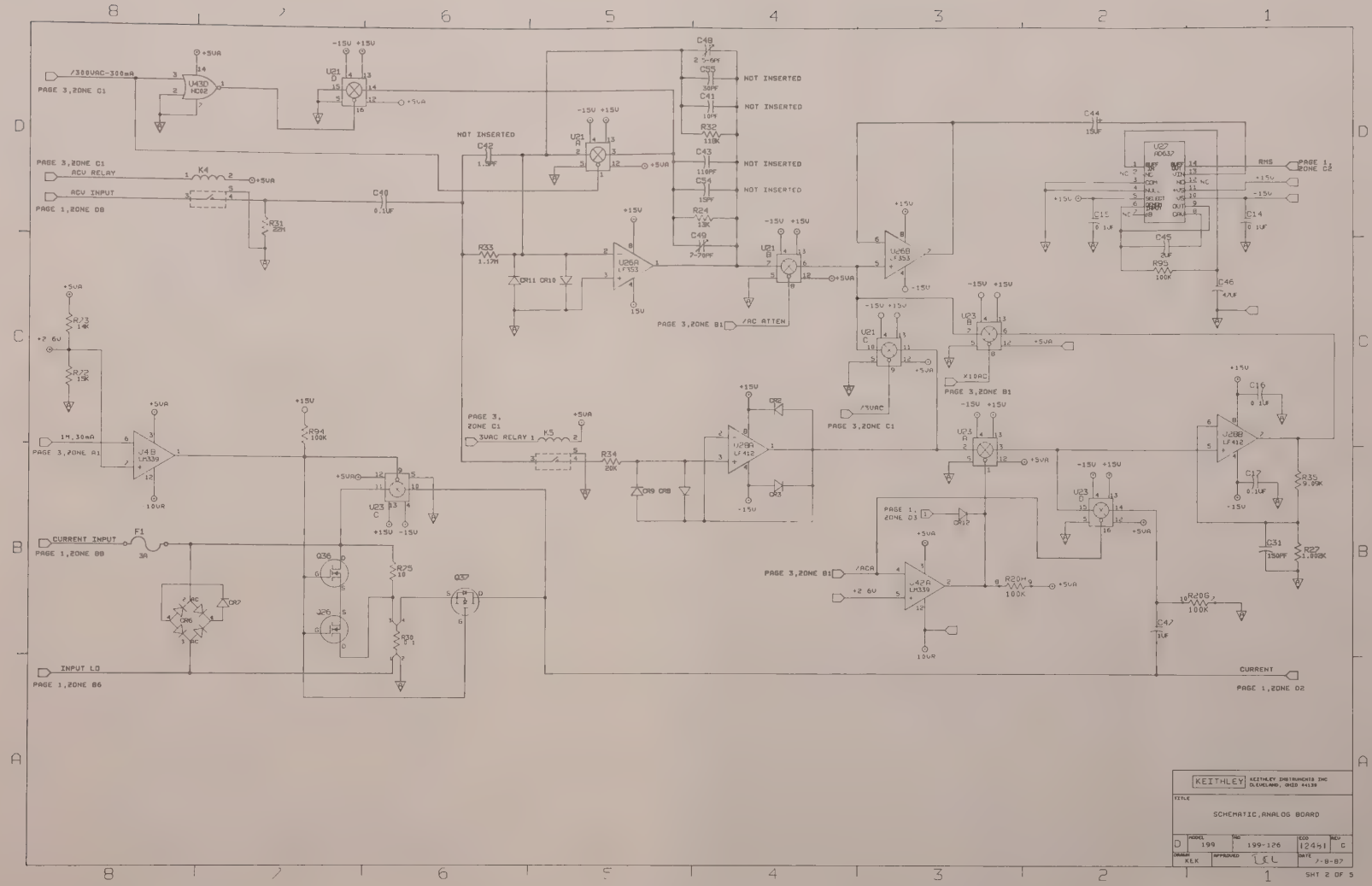


Figure 7-6. Analog Board, Schematic Diagram, Dwg. No. 199-126 (sheet 2 of 5)

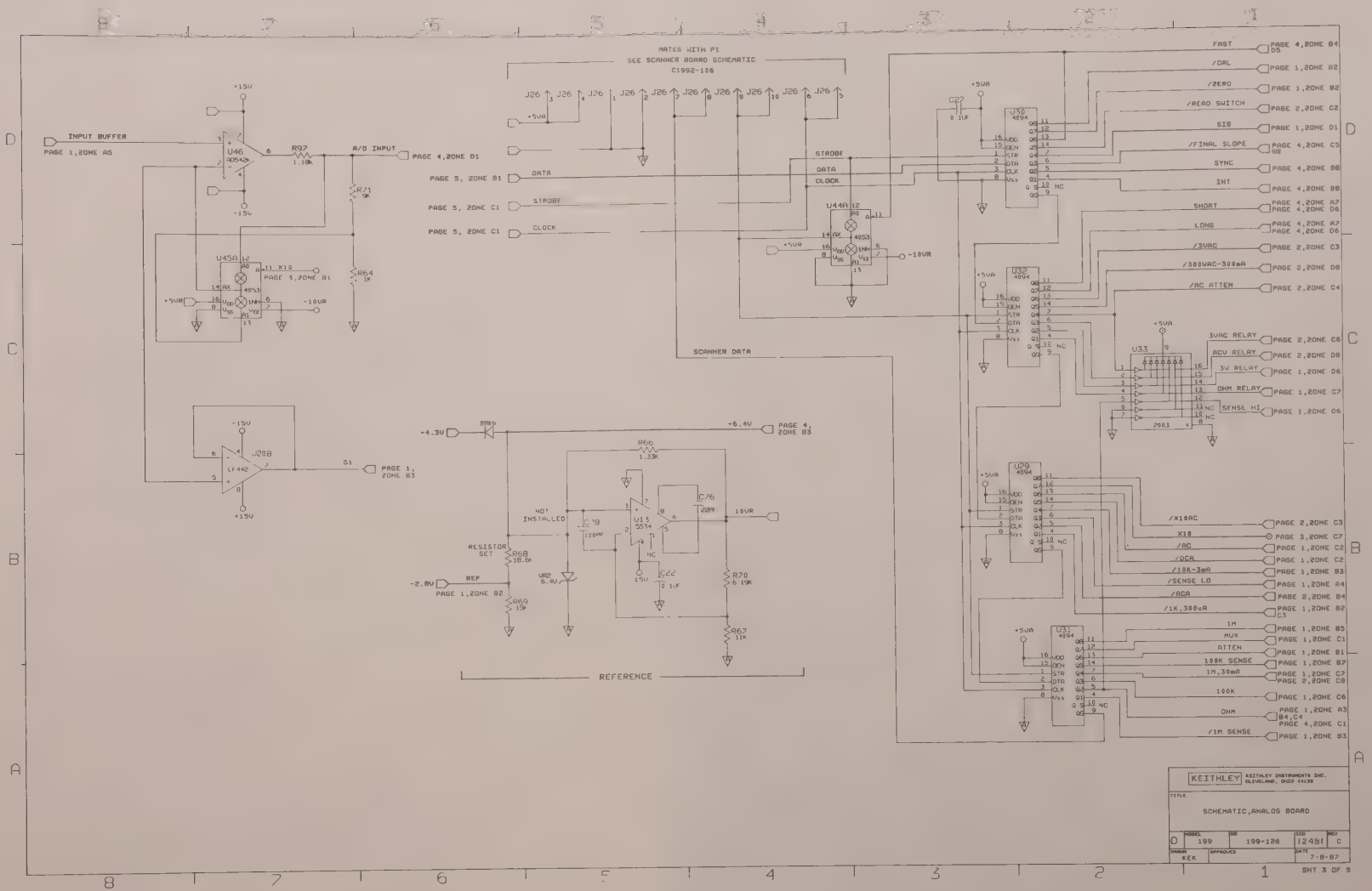


Figure 7-6. Analog Board, Schematic Diagram, Dwg. No. 199-126 (sheet 3 of 5)

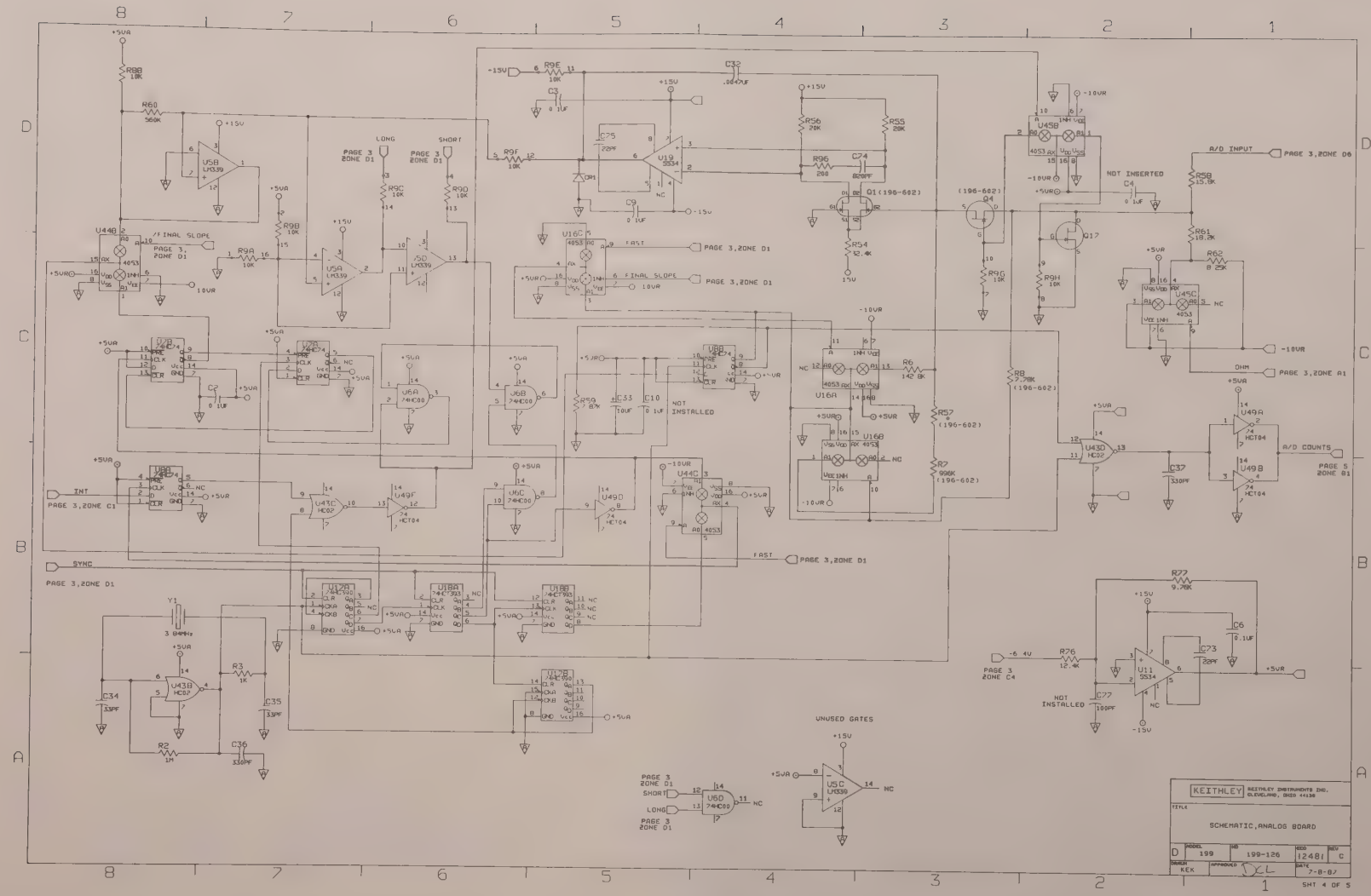


Figure 7-6. Analog Board, Schematic Diagram, Dwg. No. 199-126 (sheet 4 of 5)

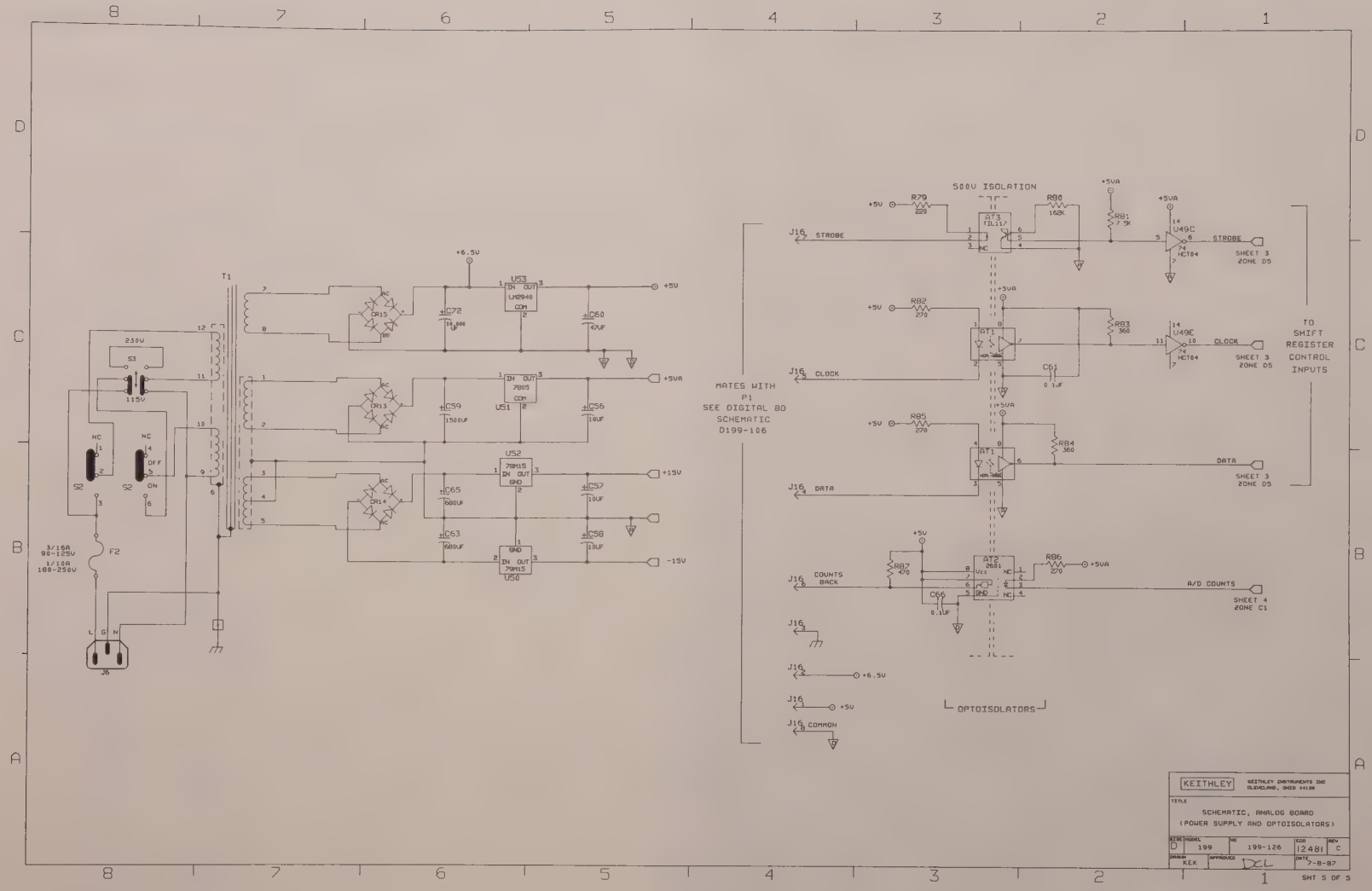


Figure 7-6. Analog Board, Schematic Diagram, Dwg. No. 199-126 (sheet 5 of 5)

TABLE 7-4. MISCELLANEOUS, PARTS LIST

CIRCUIT DESIG.	DESCRIPTION	KEITHLEY PART NO.
	BANANA JACK	BJ-12-0
	BANANA JACK	BJ-12-0
	BANANA JACK	BJ-12-2
	BANANA JACK	BJ-12-2
	BANANA JACK	BJ-12-9
	BNC CONNECTOR	CS-520
	CAPACITOR	C-64-1000p
	CONNECTOR	CS-627
	CONNECTOR	CS-627
	CONNECTOR HOUSING	CS-287-3
	COVER	D199-308
	CROSS EXTRUSION PROFILE	A199-305
	FRONT FOOT ASSEMBLY	706-317
	FRONT PANEL	D199-301
	FRONT PANEL OVERLAY	C199-309
	LINE CORD	C0-7
	LUG	LU-100
	MODIFIED CROSS EXTRUSION	B199-306
	MODIFIED SIDE EXTRUSION	C199-304
	PEM NUT	FA-18
	PEM NUT	FA-7
	PEM NUT	FA-18
	PEM STUD	FA-140-6
	PEM STUD	FA-72
	REAR FOOT	706-316
	REAR PANEL	C199-307
	SCANNER COVER PLATE	A199-317
	SIDE EXTRUSION PROFILE	A199-303
	TEST LEADS	CA-22
	WINDOW	A199-316

FASTENER

REAR BEZEL

FA-206-1

D199-302

TABLE 7-5. Model 1992, PARTS LIST

CIRCUIT DESIG.	DESCRIPTION	KEITHLEY PART No.
	CABLE ASSEMBLY	CA-64-1
	CABLE ASSEMBLY	CA-64-2
	PEM NUT	FA-7
	SCANNER BOARD SHIELD	B1992-301
	STANDOFF	ST-151-14
	#6-32x1-1/8" PHIL.PAN HD.SEMS	6-32x1-1/8PPHSEM
C1,C3	CAP,10uF,-20+100%,25V,ALUM ELEC	C-314-10
C2	CAP,.1uF,20%,50V,CERAMIC	C-365-.1
CR1	DIODE,SILICON,1N4148	RF-28
J1,J2	CONN,10 PIN OPEN END HEADER	CS-626-10
K1..K8	RELAY (DPST)	RL-77
P1	CABLE ASSEMBLY,10 CONDUCTOR	CA-32-6
P1,P2	CONN,PLUG 10 PIN W/STRESS RELIEF	CS-611-10
R1	RES,10K,5%,1/4W,COMPOSITION OR FILM	R-76-10K
U1	IC,DUAL D-TYPE FLIP FLOP,74LS74	IC-144
U2	IC,8-BIT SERIAL-IN/LTCH DRIVE,UCN-5841A	IC-536
W1	JUMPER,CIRCUIT	J-15

LTR.	ECO NO.	REVISION	ENG.	DATE
A	12296	RELEASED		10-12-87
B	12464	REVISED		11-11-87

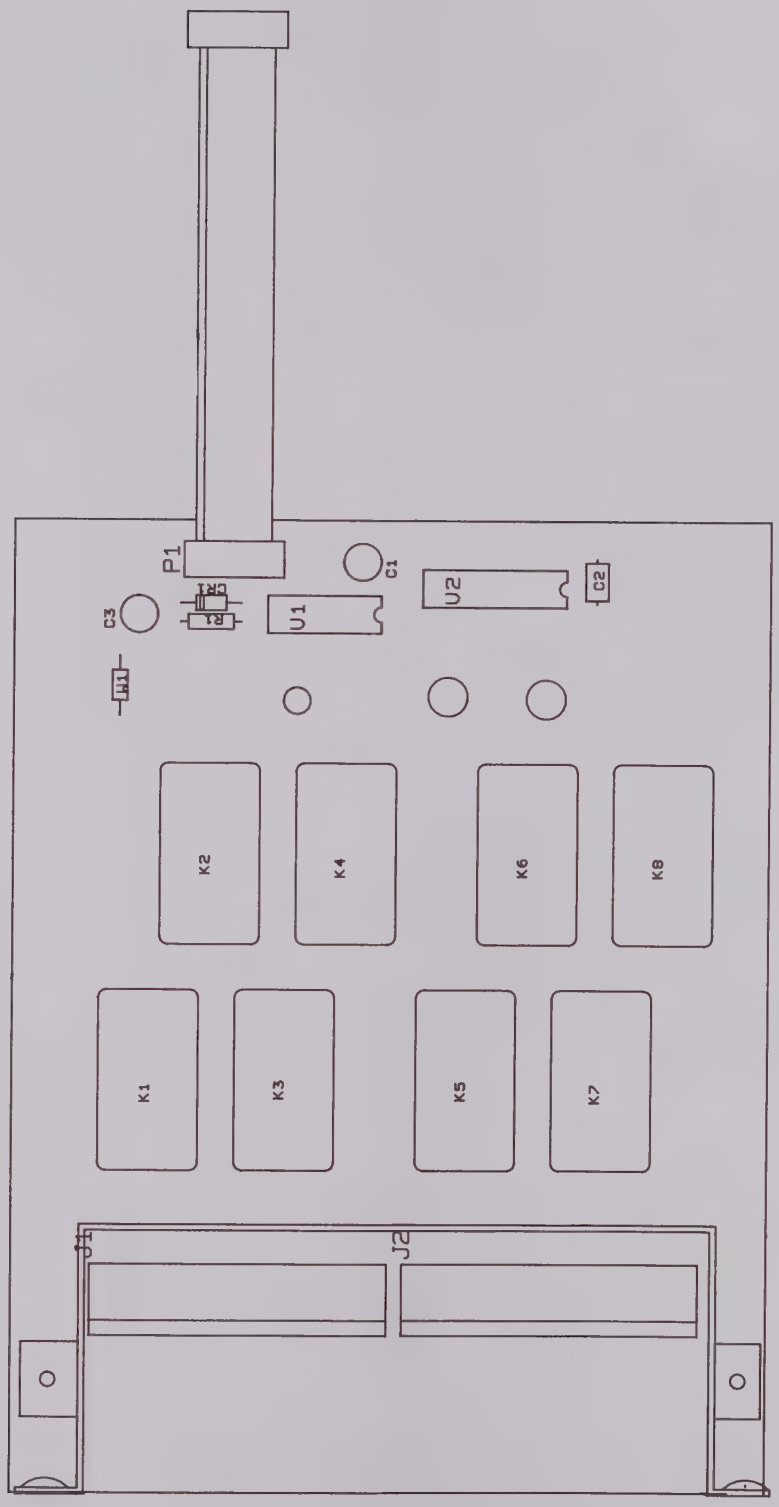


Figure 7-7. Model 1992, Component Location Drawing, Dwg. No. 1992-100

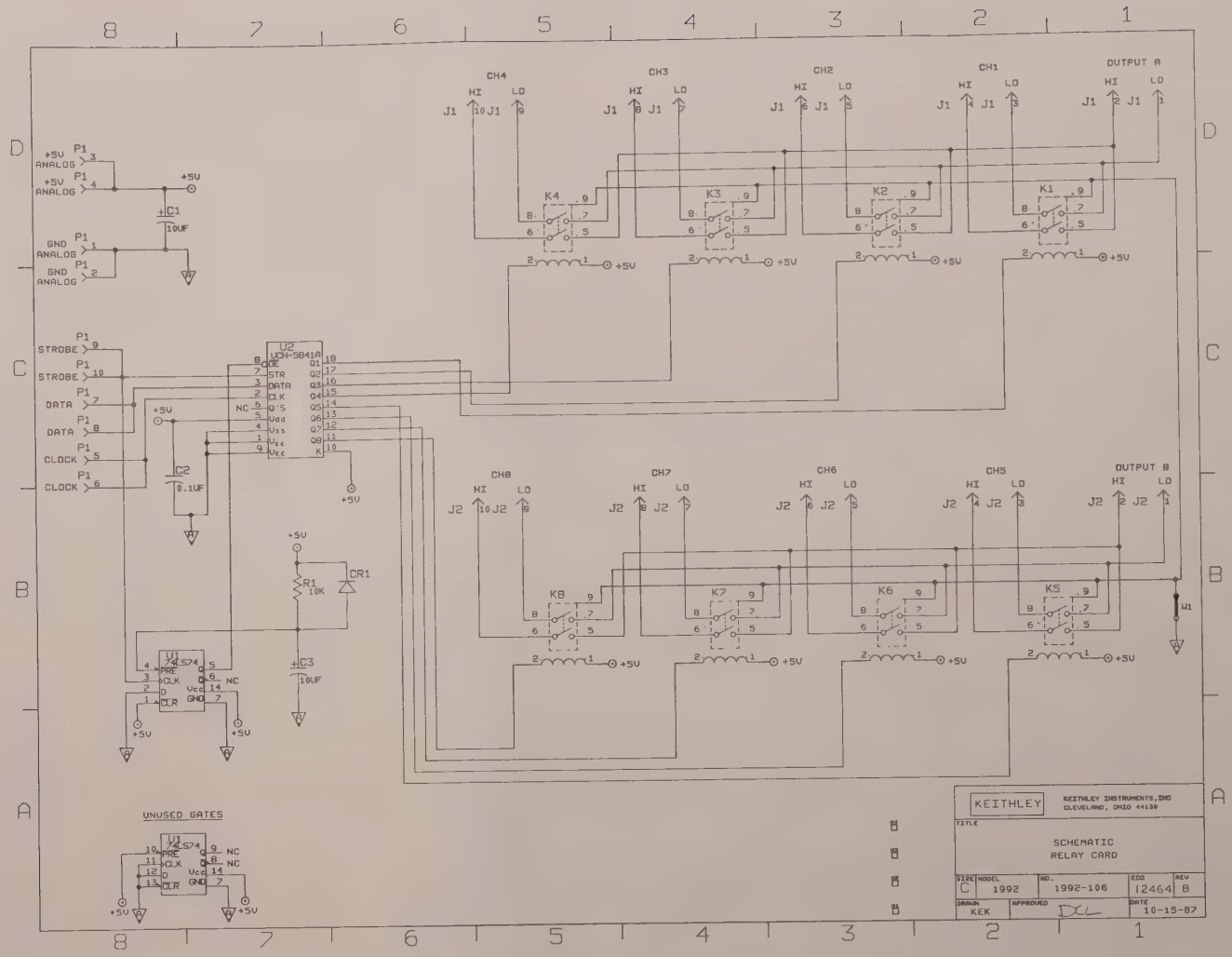


Figure 7-8. Model 1992, Schematic Diagram, Dwg. No. 1992-106

APPENDIX A

ASCII CHARACTER CODES AND IEEE-488 MULTILINE INTERFACE COMMAND MESSAGES

Decimal	Hexadecimal	ASCII	IEEE-488 Messages*
0	00	NUL	
1	01	SOH	GTL
2	02	STX	
3	03	ETX	
4	04	EOT	SDC
5	05	ENQ	PPC
6	06	ACK	
7	07	BEL	
8	08	BS	GET
9	09	HT	TCT
10	0A	LF	
11	0B	VT	
12	0C	FF	
13	0D	CR	
14	0E	SO	
15	0F	SI	
16	10	DLE	
17	11	DC1	LLO
18	12	DC2	
19	13	DC3	
20	14	DC4	DCL
21	15	NAK	PPU
22	16	SYN	
23	17	ETB	
24	18	CAN	SPE
25	19	EM	SPD
26	1A	SUB	
27	1B	ESC	
28	1C	FS	
29	1D	GS	
30	1E	RS	
31	1F	US	

* Message sent or received with ATN true.

ASCII CHARACTER CODES AND IEEE-488 MULTILINE INTERFACE COMMAND MESSAGES

Decimal	Hexadecimal	ASCII	IEEE-488 Messages*
32	20	SP	MLA 0
33	21	!	MLA 1
34	22	"	MLA 2
35	23	#	MLA 3
36	24	$	MLA 4
37	25	%	MLA 5
38	26	&	MLA 6
39	27	'	MLA 7
40	28	(	MLA 8
41	29	)	MLA 9
42	2A	*	MLA 10
43	2B	+	MLA 11
44	2C	,	MLA 12
45	2D	–	MLA 13
46	2E	.	MLA 14
47	2F	/	MLA 15
48	30	0	MLA 16
49	31	1	MLA 17
50	32	2	MLA 18
51	33	3	MLA 19
52	34	4	MLA 20
53	35	5	MLA 21
54	36	6	MLA 22
55	37	7	MLA 23
56	38	8	MLA 24
57	39	9	MLA 25
58	3A	:	MLA 26**
59	3B	;	MLA 27
60	3C	<	MLA 28
61	3D	=	MLA 29
62	3E	>	MLA 30
63	3F	?	UNL

* Message sent or received with ATN true. Numbers shown represent primary address resulting in MLA (My Listen Address).

** Model 199 default listen address.

ASCII CHARACTER CODES AND IEEE-488 MULTILINE INTERFACE COMMAND MESSAGES

Decimal	Hexadecimal	ASCII	IEEE-488 Messages*
64	40	@	MTA 0
65	41	A	MTA 1
66	42	B	MTA 2
67	43	C	MTA 3
68	44	D	MTA 4
69	45	E	MTA 5
70	46	F	MTA 6
71	47	G	MTA 7
72	48	H	MTA 8
73	49	I	MTA 9
74	4A	J	MTA 10
75	4B	K	MTA 11
76	4C	L	MTA 12
77	4D	M	MTA 13
78	4E	N	MTA 14
79	4F	O	MTA 15
80	50	P	MTA 16
81	51	Q	MTA 17
82	52	R	MTA 18
83	53	S	MTA 19
84	54	T	MTA 20
85	55	U	MTA 21
86	56	V	MTA 22
87	57	W	MTA 23
88	58	X	MTA 24
89	59	Y	MTA 25
90	5A	Z	MTA 26**
91	5B	[	MTA 27
92	5C	\	MTA 28
93	5D	]	MTA 29
94	5E	∩	MTA 30
95	5F	—	UNT

* Message sent or received with ATN true. Numbers shown are primary address resulting in MTA (My Talk Address).

**Model 199 default talk address.

ASCII CHARACTER CODES AND IEEE-488 MULTILINE INTERFACE COMMAND MESSAGES

Decimal	Hexadecimal	ASCII	IEEE-488 Messages*
96	60		MSA 0,PPE
97	61	a	MSA 1,PPE
98	62	b	MSA 2,PPE
99	63	c	MSA 3,PPE
100	64	d	MSA 4,PPE
101	65	e	MSA 5,PPE
102	66	f	MSA 6,PPE
103	67	g	MSA 7,PPE
104	68	h	MSA 8,PPE
105	69	i	MSA 9,PPE
106	6A	j	MSA 10,PPE
107	6B	k	MSA 11,PPE
108	6C	l	MSA 12,PPE
109	6D	m	MSA 13,PPE
110	6E	n	MSA 14,PPE
111	6F	o	MSA 15,PPE
112	70	p	MSA 16,PPD
113	71	q	MSA 17,PPD
114	72	r	MSA 18,PPD
115	73	s	MSA 19,PPD
116	74	t	MSA 20,PPD
117	75	u	MSA 21,PPD
118	76	v	MSA 22,PPD
119	77	w	MSA 23,PPD
120	78	x	MSA 24,PPD
121	79	y	MSA 25,PPD
122	7A	z	MSA 26,PPD
123	7B	{	MSA 27,PPD
124	7C	|	MSA 28,PPD
125	7D	}	MSA 29,PPD
126	7E	~	MSA 30,PPD
127	7F	DEL	

*Message send or received with ATN true. Numbers represent secondary address values resulting in MSA (My Secondary Address).

APPENDIX B

CONTROLLER PROGRAMS

The following programs have been supplied as a simple aid to the user and are not intended to suit specific needs. Each program allows you to send a device-dependent command string to the instrument and obtain and display an instrument reading string.

Programs for the following controllers are included:

- IBM PC or AT (with National Instruments GPIB-PC IEEE-488 Interface)
- IBM PC or AT (with Capitol Equipment Corp. PC-488 Interface)
- Apple II (equipped with the Apple II IEEE-488 Interface)
- Hewlett-Packard Model 85
- Hewlett-Packard Series 200 and 300
- Hewlett-Packard Model 9825A
- DEC LSI 11

IBM PC OR AT (NATIONAL INSTRUMENTS GPIB-PC INTERFACE)

The following program sends a command string from an IBM PC or AT computer and displays the instrument reading string on the computer CRT. The computer must be equipped with the National Instruments GPIB-PC IEEE-488 interface and the DOS 2.0 or 3.0 operating system. The GPIB-PC software must be installed and configured as described in the instruction manual.

DIRECTIONS

1. From the front panel, set the primary address of the Model 199 to 26.
2. With the power off, connect the Model 199 to the IEEE-488 interface installed in the IBM computer.
3. Type in BASICA on the computer keyboard to get into the IBM interpretive BASIC language.
4. Place the interface software disk in the default drive, type LOAD"DECL" , and press the return key.
5. Add the lines below to the declaration file; also modify the address in lines 1 and 2, as described in the GPIB-PC instruction manual.
6. Run the program and type in the desired command string. For example, to place the instrument in the ACV function and autorange, type in F1R0X and press the return key.
7. The instrument reading string will then appear on the computer screen. A typical example is: NACV+0.000000E+0.

PROGRAM	COMMENTS
`10 CLS`	Clear screen
`20 NA$=''GPIB0'':CALL IBFIND (NA$,BRD0%)`	Find board descriptor.
`30 NA$=''DEV1'':CALL IBFIND (NA$,M199%)`	Find 199 descriptor.
`40 V%=26:CALL IBPAD(M199%,V%)`	Set primary address to 26.
`50 V%=1:CALL IBSRE(BRD0%,V%)`	Set REN true.
`60 INPUT''COMMAND STRING'';C$`	Prompt for command string.
`65 C$=C$+CHR$(13)+CHR$(10)`	Add <CR> <LF> to command string.
`70 CALL IBWRT(M199%,C$)`	Send command string to 199.
`80 R$=SPACE$(25)`	Dimension reading input string.
`90 CALL IBRD(M199%,R$)`	Get reading string from 199.
`100 PRINT R$`	Display reading string on CRT.
`110 GOTO 60`	Repeat

NOTES:

1. For conversion to numeric variable, modify the program as follows:

```
100 R=VAL(MID$(R$,5,12))
105 PRINT R
```

2. In order for Translator to function properly, a <CR> <LF> sequence must be added to the end of any Translator execution string sent to the instrument. See line 65 above for an example.

IBM PC OR AT (CEC PC-488 INTERFACE)

The following program sends a command string from an IBM PC or AT computer and displays the instrument reading string on the computer CRT. The computer must be equipped with the Capitol Equipment Corp. PC-488 IEEE-488 interface. The interface card must be set to a memory address of $C400_H$, as described in the PC-488 Instruction Manual.

DIRECTIONS

1. From the front panel, set the primary address of the Model 199 to 26.
2. With the power off, connect the Model 199 to the IEEE-488 interface installed in the IBM computer.
3. Type in the program lines shown below, using the return key after each line.
4. Run the program and type in the desired command string at the command string prompt. For example, to place the instrument in the ACV function and autorange, type in F1R0X and press the return key.
5. The instrument reading string will then appear on the computer screen. A typical example is: NACV+0.000000E+0.

PROGRAM	COMMENTS
`10 DEF SEG=&HC400`	Set segment address to C400 hex.
`20 INIT=0:SEND=9:ENTER=21`	Define call offsets.
`30 MY.ADDRESS%=21:CONTROLLER%=0`	Define interface parameters.
`40 ADDRESS%=26`	Set 199 address to 26.
`50 CALL INIT(MY.ADDRESS%, CONTROLLER%)`	Initialize PC-488.
`60 INPUT''COMMAND STRING'';C$`	Prompt for command string.
`65 C$=C$+CHR$(13)`	Add <CR> to string.
`70 CALL SEND(ADDRESS%,C$,STATUS%)`	Send command string to 199.
`80 R$=SPACE$(25)`	Dimension reading input string.
`90 CALL ENTER(R$,LENGTH%,ADDRESS%, STATUS%)`	Get reading string from 199.
`100 PRINT R$`	Display reading string.
`110 GOTO 60`	Repeat.

NOTES:

1. To convert from a string to a numeric variable, modify the program as follows:

```
100 R=VAL(MID$(R$,5,12))
105 PRINT R
```

2. For use with a card memory address other than $C400_H$, modify the DEF SEG statement in line 10 accordingly. For example, with a card memory address of $C000_H$, line 10 should be modified as follows:

```
10 DEF SEG=&HC000
```

3. In order for Translator to function properly, a <CR> sequence should be added to the end of any string sent to the Model 199. See the example is line 65 above.

APPLE II (APPLE II IEEE-488 INTERFACE)

The following program sends a command string to the Model 199 from an Apple II computer and displays the instrument reading string on the computer CRT.

The computer must be equipped with the Apple II IEEE-488 Interface installed in slot 3.

DIRECTIONS

1. From the front panel, set the primary address of the Model 199 to 26.
2. With the power off, connect the Model 199 to the IEEE-488 interface installed in the Apple II computer.
3. Enter the lines in the program below, using the RETURN key after each line.
4. Run the program and type in the desired command string at the command prompt. For example, to place the instrument in ACV and autorange, type in F1R0X and press the return key.
5. The instrument reading string will then appear on the CRT. A typical display is: NACV+0.00000E+0.

PROGRAM	COMMENTS
`10 Z$=CHR$(26)`	Terminator.
`20 INPUT''COMMAND STRING?'';B$`	Prompt for and enter command string.
`30 PR#3`	Set output to IEEE-488 bus.
`40 IN#3`	Define input from IEEE-488 bus.
`50 PRINT''RA''`	Enable remote.
`60 PRINT''WT:'':Z$;B$`	Address 199 to listen, send string.
`70 PRINT''LF1''`	Line feed on.
`80 PRINT''RDZ'';Z$;:INPUT'' '';A$`	Address 199 to talk, input data.
`90 PRINT''UT''`	Untalk the 199.
`100 PR#0`	Define output to CRT.
`110 IN#0`	Define input from keyboard.
`120 PRINT A$`	Display reading string.
`130 GOTO 20`	Repeat.

NOTES:

1. If conversion to numeric variable is required, make the following changes:

```
120 A=VAL(MID$(A$,5,12))
125 PRINT A
```

2. The Apple II terminates on commas in the data string. To avoid problems, program the Model 199 for the B0G0 or B0G1 data format to eliminate commas.

HEWLETT-PACKARD MODEL 85

The following program sends a command string to the Model 199 from an HP-85 computer and displays the instrument reading string on the computer CRT. The computer must be equipped with the HP82937 GPIB Interface and an I/O ROM.

DIRECTIONS

1. From the front panel, set the primary address of the Model 199 to 26.
2. With the power off, connect the Model 199 to the HP82937A GPIB interface installed in the HP-85 computer.
3. Enter the lines in the program below, using the END LINE key after each line.
4. Press the HP-85 RUN key and type in the desired command string at the command prompt. For example, to place the instrument in ACV and autorange, type in F1R0X and press the END LINE key.
5. The instrument reading string will then appear on the CRT. A typical display is: NACV+0.000000E+0.

PROGRAM	COMMENTS
`10 DIM A$[25],B$[25]`	Dimension strings.
`20 REMOTE 726`	Place 199 in remote.
`30 DISP''COMMAND STRING'';`	Prompt for command.
`40 INPUT A$`	Input command string.
`50 OUTPUT 726; A$`	Address 199 to listen, send string.
`60 ENTER 726; B$`	Address 199 to talk, input reading.
`70 DISP B$`	Display reading string.
`80 GOTO 30`	Repeat
`90 END`	

NOTE: For conversion to numeric variable, change line 70 as follows:

```
70 DISP VAL(B$[5])
```

HEWLETT-PACKARD SERIES 200 and 300

The following program sends a command string to the Model 199 from a Hewlett-Packard Series 200 or 300 computer and displays the instrument reading string on the computer CRT. The computer must be equipped with the HPIB Interface and BASIC 2.0, 3.0, or 4.0.

DIRECTIONS

1. From the front panel, set the primary address of the Model 199 to 26.
2. With the power off, connect the Model 199 to the HPIB interface installed in the computer.
3. Enter the computer EDIT mode.
4. Enter the lines in the program below, using the ENTER key after each line.
5. Run the program, and type in the desired command string at the command prompt. For example, to place the instrument in ACV and autorange, type in F1R0X and press the ENTER key.
6. The instrument reading string will then appear on the CRT. A typical display is: NACV+0.000000E+0.

PROGRAM	COMMENTS
`10 REMOTE 726`	Place 199 in remote.
`15 DIM A$[25], B$[25]`	
`20 INPUT''COMMAND STRING'',A$`	Prompt for and input command.
`30 OUTPUT 726; A$`	Address 199 to listen, send string.
`40 ENTER 726; B$`	Address 199 to talk, input reading.
`50 PRINT B$`	Display reading string.
`60 GOTO 20`	Repeat.
`70 END`	

NOTE: For conversion to a numeric variable, change the program as follows:

```
40 ENTER 726;B
50 PRINT B
```

HEWLETT-PACKARD MODEL 9825A

Use the following program to send a command string to the Model 199 from a Hewlett-Packard Model 9825A and display the instrument reading string on the computer printer. The computer must be equipped with the HP98034A HPIB Interface and a 9872A extended I/O ROM.

DIRECTIONS

1. From the front panel, set the primary address of the Model 199 to 26.
2. With the power off, connect the Model 199 to the 98034A HPIB interface installed in the 9825A.
3. Enter the lines in the program below, using the STORE key after each line. Line numbers are automatically assigned by the 9825A.
4. Press the 9825A RUN key and type in the desired command string at the command prompt. For example, to place the instrument in ACV and autorange, type in F1R0X and press the CONT key.
5. The instrument reading string will then appear on the computer print out. A typical display is: NACV+0.000000E+0.

PROGRAM	COMMENTS
`0 dim A$[25],B$[25]`	Dimension data strings.
`1 dev''199'',726`	Define 199 at address 26.
`2 rem''199''`	Place 199 in remote.
`3 ent''COMMAND STRING'',B$`	Prompt for command string.
`4 wrt''199'',B$`	Address 199 to listen, send string.
`5 red''199'',A$`	Address 199 to talk, input data.
`6 prt A$`	Print data string on printer.
`7 gto 3`	Repeat.

NOTE: For conversion to numeric variable, modify the program as follows:

```
6 prt val(A$[5])
```

DEC LSI 11

The following program sends a command string to the Model 199 from a DEC LSI 11 minicomputer and displays the instrument reading string on the DEC CRT terminal. The LSI 11 must be configured with 16K words of RAM and an IBV 11 IEEE-488 interface. The software must be configured with the IB software as well as FORTRAN and the RT 11 operating system.

DIRECTIONS

1. From the front panel program feature, set the primary address of the Model 199 to 26.
2. With the power off, connect the Model 199 to the IBV 11 IEEE-488 interface cable.
3. Enter the program below, using the editor under RT 11 and the name IEEE.FOR.
4. Compile using the FORTRAN compiler as follows: FORTRAN IEEE.
5. Link with the system and IB libraries as follows: LINK IEEE,IBLIB.
6. Type RUN IEEE and press the RETURN key.
7. The display will read "ENTER ADDRESS".
8. Type in 26 and press the RETURN key.
9. The display will read "TEST SETUP".
10. Type in the desired command string and press the RETURN key. For example, to program the instrument for ACV and autorange, type in F1R0X and press RETURN.
11. The instrument data string will appear on the computer display. A typical display is: NACV+0.000000E+0.

PROGRAM	COMMENTS
`PROGRAM IEEE`	
`INTEGER*2 PRIADR`	
`LOGICAL*1 MSG(80),INPUT(80)`	
`DO 2 I = 1,10`	
`CALL IBSTER(I,0)`	Turn off IB errors.
`2 CONTINUE`	
`CALL IBSTER(15,5)`	Allow 5 error 15's.
`CALL IBTIMO(120)`	Allow 1 second bus timeout.
`CALL IBTERM(10)`	Set line feed as terminator.
`CALL IBREN`	Turn on remote.
`4 TYPE 5`	
`5 FORMAT (1X,'ENTER ADDRESS:',$)`	Input primary address.
`ACCEPT 10,PRIADR`	
`10 FORMAT (I2)`	
`12 TYPE 15`	
`15 FORMAT (1X,'TEST SETUP:',$)`	Prompt for command string.
`CALL GETSTR (5,MSG,72)`	Program instrument.
`CALL IBSEOI (MSG,-1,PRIADR)`	Address 199 to listen, send string.
`18 I=IBRECV (INPUT,80,PRIADR)`	Get data from instrument.
`INPUT (I+1) = 0`	
`CALL PUTSTR (7,INPUT,'0')`	
`CALL IBUNT`	Untalk the 199.
`GOTO 12`	Repeat.
`END`	

APPENDIX C

IEEE-488 BUS OVERVIEW

BUS DESCRIPTION

The IEEE-488 bus, which is also frequently referred to as the GPIB (General Purpose Interface Bus), was designed as a parallel transfer medium to optimize data transfer with a minimum number of bus lines. In keeping with this goal, the bus has eight data lines that are used both for data and many commands. Additionally, the bus has five management lines, which are used to control bus operation, and three handshake lines that are used to control the data byte transfer sequence.

A typical configuration for controlled bus operation is shown in Figure D-1. A typical system will have one controller and one or more devices to which commands are given and, in most cases, from which data is received. Generally, there are three categories that describe device operation: controller, talker, and listener.

The controller does what its name implies: it controls other devices on the bus. A talker sends data (usually to the controller), and a listener receives data. Depending on the instrument, a particular device may be a talker only, a listener only, or both a talker and a listener. The Model 199 has both talker and listener capabilities.

There are two categories of controllers: system controller and basic controller. Both are able to control other devices, but only the system controller has absolute authority in the system. In a system with more than one controller, only one controller may be active at any given time. Certain command protocol allows control to be passed from one controller to another.

The bus is limited to 15 devices, including the controller. Thus, any number of devices may be present on the bus at one time. Although several active listeners may be present simultaneously, only one active talker may be present on the bus, or communications would be scrambled.

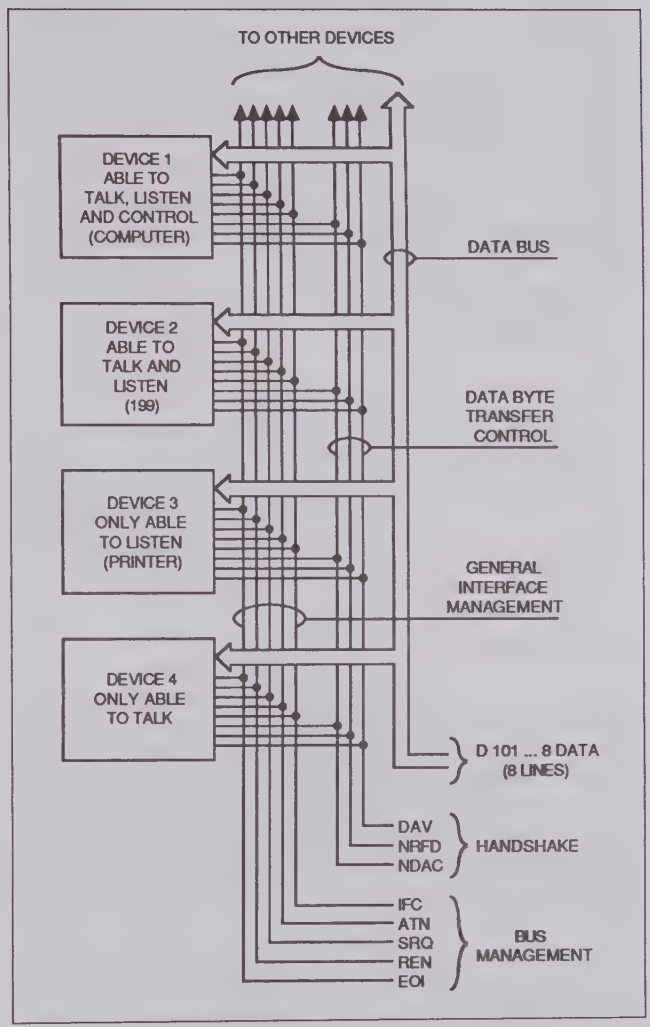


Figure C-1. IEEE Bus Configuration

A device is placed in the talk or listen mode from the controller by sending an appropriate talk or listen command. These talk and listen commands are derived from an instrument's primary address. The primary address may have any value between 0 and 30 and is generally set by rear panel switches or programmed in from the front panel (as in the case of the Model 199). The actual listen command value sent over the bus is derived by ORing the primary address with $20 (the $ symbol preceding the number designates a hexadecimal, or base 16 value). For example, if the primary address is 26 (the default Model 199 value), the actual listen command byte value is $3A ($1A + $20 = $3A). In a similar manner, the talk command byte is derived by ORing the primary address with $40. With a primary address of 26, the actual talk command byte would be $4A ($40 + $1A = $4A).

The IEEE-488 standards also include another addressing mode called secondary addressing. Secondary address byte values lie in the range of $60-$7F. Note, however, that many devices, including the Model 199, do not use secondary addressing.

Once the device is properly addressed, bus transmission sequences are set to take place. For example, if an instrument is addressed to talk, it will usually output its data string on the bus one byte at a time. The listening device (frequently the controller) will then read this information as transmitted.

BUS LINES

The signal lines on the IEEE-488 bus are grouped into three categories: data lines, management lines, and handshake lines. The eight data lines handle bus data and many commands, while the management and handshake lines ensure orderly bus operation. Each bus line is active low with approximately zero volts representing logic 1 (true). The following paragraphs briefly describe the operation of these lines.

Data Lines

The bus uses eight data lines to transmit and receive data in bit-parallel, byte serial fashion. These lines use the convention DIO1-DIO8 instead of the more common D0-D7. DIO1 is the least significant bit, while DIO8 is the most significant bit. The data lines are bidirectional (with most devices), and, as with the remaining bus lines, low is considered to be true.

Bus Management Lines

The five bus management lines ensure proper interface control and management. These lines are used to send uniline commands.

ATN (Attention)—The state of ATN determines how information on the data lines is to be interpreted.

IFC (Interface Clear)—IFC allows the clearing of active talkers or listeners from the bus.

REN (Remote Enable)—REN is used to place devices in the remote mode. Usually, devices must be in remote before they can be programmed over the bus.

EOI (End Or Identify)—EOI is used to mark the end of a multi-byte data transfer sequence. EOI is also used along with ATN, to send the IDY (identify) message for parallel polling.

SRQ (Service Request)—SRQ is used by devices to request service from the controller.

Handshake Lines

Three handshake lines that operate in an interlocked sequence are used to ensure reliable data transmission regardless of the transfer rate. Generally, data transfer will occur at a rate determined by the slowest active device on the bus. These handshake lines are:

DAV (Data Valid)—The source (talker) controls the state of DAV to indicate to any listeners when data is valid.

NRFD (Not Ready For Data)—The acceptor (listener) controls the state of NRFD. It is used to signal the transmitting device to hold off the byte transfer sequence until the accepting device is ready.

NDAC (Not Data Accepted)—NDAC is also controlled by the accepting device. The state of NDAC tells the source whether or not the device has accepted the data byte.

Figure C-2 shows the basic handshake sequence for the transmission of one data byte. This sequence is used to transfer data, talk and listen addresses, as well as multiline commands.

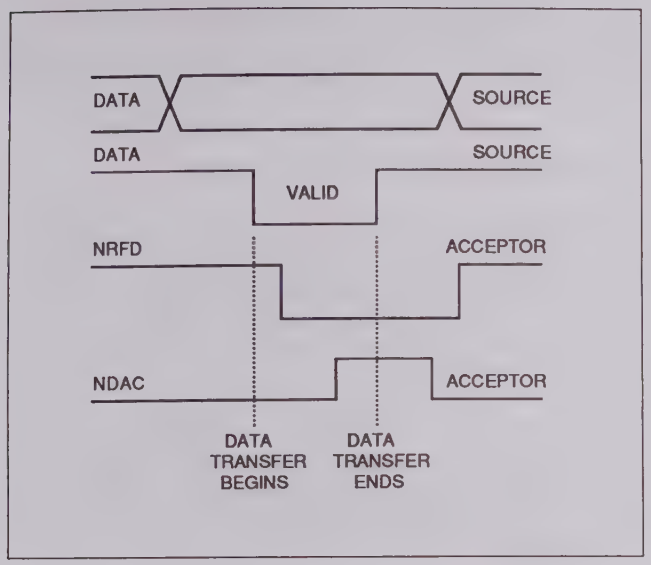


Figure C-2. IEEE Handshake Sequence

BUS COMMANDS

Commands associated with the IEEE-488 bus can be grouped into the following three general categories. Refer to Table C-1.

Uniline Commands—These commands are asserted by setting the associated bus line true. For example, to assert REN (Remote Enable), the REN line would be set low (true).

Multiline Commands—General bus commands which are sent over the data lines with the ATN line true.

Device-dependent Commands—Commands whose meanings depend on the device in question. These commands are transmitted via the data lines while ATN is false.

Table C-1. IEEE-488 Bus Command Summary

Command Type	Command	State of ATN Line*	Comments
Uniline	REN (Remote Enable)	X	Sets up devices for remote operation.
	EOI	X	Marks end of transmission.
	IFC (Interface Clear)	X	Clears Interface.
	ATN (Attention)	Low	Defines data bus contents.
	SRQ	X	Controlled by external device.
Multiline			
Universal	LLO (Local Lockout)	Low	Locks out local operation.
	DCL (Device Clear)	Low	Returns device to default conditions.
	SPE (Serial Enable)	Low	Enables serial polling.
	SPD (Serial Poll Disable)	Low	Disables serial polling.
Addressed	SDC (Selective Device Clear)	Low	Returns unit to default conditions.
	GTL (Go To Local)	Low	Returns device to local.
	GET (Group Execute Trigger)	Low	Triggers device for reading.
Unaddressed	UNL (Unlisten)	Low	Removes all listeners from bus.
	UNT (Untalk)	Low	Removes any talkers from bus.
Device-dependent		High	Programs Model 199 for various modes.

*Don't Care.

Uniline Commands

The five uniline commands include REN, EOI, IFC, ATN, and SRQ. Each command is associated with a dedicated bus line, which is set low to assert the command in question.

REN (Remote Enable)—REN is asserted by the controller to set up instruments on the bus for remote operation. When REN is true, devices will be removed from the local mode. Depending on device configuration, all front panel controls except the LOCAL button (if the device is so equipped) may be locked out when REN is true. Generally, REN should be asserted before attempting to program instruments over the bus.

EOI (End or Identify)—EOI may be asserted either by the controller or by external devices to identify the last byte in a multi-byte transfer sequence, allowing data words of various lengths to be transmitted.

IFC (Interface Clear)—IFC is asserted by the controller to clear the interface and return all devices to the talker and listener idle states.

ATN (Attention)—The controller asserts ATN while sending addresses or multiline commands.

SRQ (Service Request)—SRQ is asserted by a device on the bus when it requires service from the controller.

Universal Multiline Commands

Universal multiline commands are those commands that required no addressing as part of the command sequence. All devices equipped to implement these commands will do so simultaneously when the commands are transmitted. As with all multiline commands, these commands are transmitted with ATN true.

LLO (Local Lockout)—LLO is sent to instruments to lock out front panel or local operation of the instrument.

DCL (Device Clear)—DCL is used to return instruments to some default state. Usually, devices return to their power-up conditions.

SPE (Serial Poll Enable)—SPE is the first step in the serial polling sequence, which is used to determine which device on the bus is requesting service.

SPD (Serial Poll Disable)—SPD is used by the controller to remove all devices on the bus from the serial poll mode and is generally the last command in the serial polling sequence.

Addressed Multiline Commands

Addressed multiline commands are those commands that must be preceded by an appropriate listen address before the instrument will respond to the command in question. Note that only the addressed device will respond to the command. Both the command and the address preceding it are sent with ATN true.

SDC (Selective Device Clear)—The SDC command performs essentially the same function as DCL except that only the addressed device responds. Generally, instruments return to their power-up default conditions when responding to SDC.

GTL (Go To Local)—GTL is used to remove instruments from the remote mode and place them in local. With many instruments, GTL may also restore operation of front panel controls if previously locked out.

GET (Group Execute Trigger)—GET is used to trigger devices to perform a specific action that will depend on device configuration (for example, perform a measurement sequence). Although GET is an addressed command, many devices may respond to GET without addressing.

Address Commands

Addressed commands include two primary command groups, and a secondary address group. ATN is true when these commands are asserted. These commands include:

LAG (Listen Address Group)—These listen commands are derived from an instrument's primary address and are used to address devices to listen. The actual command byte is obtained by ORing the primary address with $20.

TAG (Talk Address Group)—The talk commands are derived from the primary address by ORing the address with $40. Talk commands are used to address devices to talk.

SCG (Secondary Command Group)—Commands in this group provide additional addressing capabilities. Many devices (including the Model 199) do not use these commands.

Unaddress Commands

The two unaddress commands are used by the controller to remove any talkers or listeners from the bus. ATN is true when these commands are asserted.

UNL (Unlisten)—Listeners are placed in the listener idle state by UNL.

UNT (Untalk)—Any previously commanded talkers will be placed in the talker idle state by UNT.

Device-Dependent Commands

The purpose of device-dependent commands will depend on instrument configuration. Generally, these commands are sent as one or more ASCII characters that command the device to perform a specific action. For example, the command string R0X is used to control the measurement range of the Model 199.

The IEEE-488 bus treats these commands as data in that ATN is false when the commands are transmitted.

Command Codes

Command codes for the various commands that use the data lines are summarized in Figure C-3. Hexadecimal and and decimal values for the various commands are listed in Table C-2.

BITS D_4 D_5 D_6 D_7					X 0 0 0 0		X 0 0 0 1		X 0 0 1 0		X 0 0 1 1		X 0 1 0 0		X 0 1 0 1		X 0 1 1 0		X 0 1 1 1		X 1 0 0 0		X 1 0 0 1		X 1 0 1 0		X 1 0 1 1		X 1 1 1 1	
D_3	D_2	D_1	D_0	COLUMN→ ROW↓	0(A)	0(B)	1(A)	1(B)	2(A)	2(B)	3(A)	3(B)	4(A)	4(B)	5(A)	5(B)	6(A)	6(B)	7(A)	7(B)
0	0	0	0	0	NUL		DLE		SP	0	0	16	@	O	P	16			p	
0	0	0	1	1	SOH	GTL	DC1	LLO	!	1	1	17	A	1	Q	17	a		q	
0	0	1	0	2	STX		DC2		"	2	2	18	B	2	R	18	b		r	
0	0	1	1	3	ETX		DC3		#	3	3	19	C		S	19	c		s	
0	1	0	0	4	EOT	SDC	DC4	DCL	$	4	4	20	D	4	T	20	d		t	
0	1	0	1	5	ENQ	PPC*	NAK	PPU*	%	5	5	21	E	5	U	21	e		u	
0	1	1	0	6	ACK		SYN		&	6	6	22	F	6	V	22	f		v	
0	1	1	1	7	BEL		ETB		'	7	7	23	G	7	W	23	g		w	
1	0	0	0	8	BS	GET	CAN	SPE	(	8	8	24	H	8	X	24	h		x	
1	0	0	1	9	HT	TCT*	EM	SPD	)	9	9	25	I	9	Y	25	i		y	
1	0	1	0	10	LF		SUB		*	10	:	26	J	10	Z	26	j		z	
1	0	1	1	11	VT		ESC		+	11	;	27	K	11	[	27	k		{	
1	1	0	0	12	FF		FS		,	12	<	28	L	12	\	28	l		|	
1	1	0	1	13	CR		GS		-	13	=	29	M	13	]	29	m		}	
1	1	1	0	14	SO		RS		.	14	>	30	N	14	∩	30	n		~	
1	1	1	1	15	SI		US		/	15	?	UNL	O	15	—	UNT	o		DEL	

ADDRESSED COMMAND GROUP (ACG)

UNIVERSAL COMMAND GROUP (UCG)

LISTEN ADDRESS GROUP (LAG)

TALK ADDRESS GROUP (TAG)

PRIMARY COMMAND GROUP (PCG)

SECONDARY COMMAND GROUP (SDC)

*PPC (PARALLEL POLL CONFIGURE), PPU (PARALLEL POLL UNCONFIGURE), AND TCT (TAKE CONTROL) NOT IMPLEMENTED BY MODEL 199.

NOTE: D_0 = DIO1 ... D_7 = DIO8

X = DON'T CARE

Figure C-3. Command Codes

Table C-2. Hexadecimal and Decimal Command Codes

Command	Hex Value	Decimal Value
GTL	01	1
SDC	04	4
GET	08	8
LLO	11	17
DCL	14	20
SPE	18	24
SPD	19	25
LAG	20-3F	32-63
TAG	40-5F	64-95
SGG	60-7F	96-127
UNL	3F	63
UNT	5F	95

Typical Command Sequences

For the various multiline commands, a specific bus sequence must take place to properly send the command. In particular, the correct listen address must be sent to the instrument before it will respond to addressed commands. Table C-3 lists a typical bus sequence for sending an addressed multiline command. In this instance, the SDC command is being sent to the instrument. UNL is generally sent as part of the sequence to ensure that no other active listeners are present. Note that ATN is true for both the listen command and the SDC command byte itself.

Table C-3. Typical Addressed Command Sequence

			Data Bus		
Step	Command	ATN State	ASCII	Hex	Decimal
1	UNL	Set low	?	3F	63
2	LAG*	Stays low	:	3A	58
3	SDC	Stays low	EOT	04	4
4		Returns high			

*Assumes primary address = 26.

Table C-4 gives a typical device-dependent command sequence. In this instance, ATN is true while the instrument is being addressed, but it is set high while sending the device-dependent command string.

Table C-4. Typical Device-Dependent Command Sequence

			Data Bus		
Step	Command	ATN State	ASCII	Hex	Decimal
1	UNL	Set low	?	3F	63
2	LAG*	Stays low	:	3A	58
3	Data	Set high	R	52	82
4	Data	Stays high	0	30	48
5	Data	Stays high	X	58	88

*Assumes primary address = 26.

IEEE Command Groups

Command groups supported by the Model 199 are listed in Table C-5. Device-dependent commands are not included in this list.

Table C-5. IEEE Command Group

HANDSHAKE COMMAND GROUP
DAC=DATA ACCEPTED
RFD=READY FOR DATA
DAV=DATA VALID

UNIVERSAL COMMAND GROUP
ATN=ATTENTION
DCL=DEVICE CLEAR
IFC=INTERFACE CLEAR
LLO=LOCAL LOCKOUT
REN=REMOTE ENABLE
SPD=SERIAL POLL DISABLE
SPE=SERIAL POLL ENABLE

ADDRESS COMMAND GROUN
LISTEN: LAG=LISTEN ADDRESS GROUP
MLA=MY LISTEN ADDRESS
UNL=UNLISTEN
TALK: TAG=TALK ADDRESS GROUP
MTA=MY TALK ADDRESS
UNT=UNTALK
OTA=OTHER TALK ADDRESS

ADDRESSED COMMAND GROUP
ACG=ADDRESSED COMMAND GROUP
GET=GROUP EXECUTE TRIGGER
GTL=GO TO LOCAL
SDC=SELECTIVE CLEAR

STATUS COMMAND GROUP
RQS=REQUEST SERVICE
SRQ=SERIAL POLL REQUEST
STB=STATUS BYTE
EOI=END

KEITHLEY

SERVICE FORM

Model No. _____ **Serial No.** _____ **P.O. No.** _____ **Date** _____

Name _____ **Phone** _____

Company _____

Address _____

City _____ **State** _____ **Zip** _____

List all control settings and describe problem. _____

_____

_____

_____ (Attach additional sheets as necessary.)

Show a block diagram of your measurement system including all instruments connected (whether power is turned on or not). Also describe signal source.

Where is the measurement being performed? (factory, controlled laboratory, out-of-doors, etc.) _____

What power line voltage is used? _____ Variation? _____

Frequency? _____ Ambient Temperature? _____ °F.

Variation? _____ °F. Rel. Humidity? _____ Other? _____

Any additional information. (If special modifications have been made by the user, please describe below.)

_____

_____

*Be sure to include your name and phone number on this service form.

MP MASTER
MA24765

KEITHLEY

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